NOVEL WINE POURING MACHINE

FINAL DESIGN REPORT

PRESENTED BY THE CORK AND GEAR TEAM

Erin Clark

Berkeley Davis

Jacob Rardin

Julia Trenkle

Brett Wittmuss

CorkAndGear@gmail.com

Mechanical Engineering Department

California Polytechnic State University

San Luis Obispo

June 1, 2018

PREPARED FOR

Bill Swanson

Center of Effort, Arroyo Grande, CA

STATEMENT OF DISCLAIMER

Since this project is a result of a class assignment, it has been graded and accepted as fulfillment of the course requirements. Acceptance does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

ABSTRACT

This Final Design Report outlines the "Novel Wine Opener" senior design project completed by a team of mechanical engineering students at California Polytechnic State University, San Luis Obispo. The project was sponsored by Bill Swanson, owner of the Center of Effort vineyard and winery in Edna Valley, CA. The goal of the project was to produce a novel wine pouring machine for the Center of Effort. This device should be able to remove the foil cap from a wine bottle, uncork the bottle, and pour a glass of wine at the winery and at public events. The finished product should fit the aesthetic of the remodeled winery and serve as an attraction for wine tasting visitors.

After determining our sponsor's needs and wants for the project, we refined the problem into a set of engineering specifications. Existing technologies were researched and compared to identify similar developments already on the market. The lack of similar technologies found confirmed the presence of a need that our project seeks to fill.

The first step we took in tackling this design challenge was to divide the project into six subsystems: bottle gripping, foil removal, cork removal, lifting and pouring, pour volume sensing, and user interface. Our leading concepts comprise a rotating tower for foil and cork removal, a pivoting pouring tower to hold and pour the bottle, a load cell to measure the pour volume, and mechanical buttons and toggle switches for user interface. To verify the feasibility of our designs, we built conceptual and structural prototypes of the rotating tower, cork remover, and foil cutter.

The next step in the design process was to redesign each individual function as needed. Prototyping highlighted areas in need of design changes. These changes were implemented, and new prototypes were made. This cycle continued until each individual function operated successfully. The final design consists of improved versions of the leading concepts selected before prototyping: rotating tower, pouring tower, bottle gripper, load cell weight sensing mechanism, and user interface.

Next, the final design was manufactured and assembled with final materials. Most prototyping materials included plywood and acrylic. These materials were switched out with aluminum parts. After each function was successfully manufactured and functional, all subsystems were integrated together onto one base plate. Some redesigning and remanufacturing were necessary for successful integration of the entire device. Once the device was satisfactorily assembled, the device was tested against the engineering specifications originally identified at the beginning of the project. This document contains the research, ideation processes, design decisions, design outcomes, manufacturing processes, and test results of the entire process to date.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Bill Swanson, owner of the Center of Effort vineyard and winery, reached out to the Mechanical Engineering department at California Polytechnic State University, San Luis Obispo, to create a novel wine opening and pouring machine to match the aesthetic of his winery. The purpose of this machine is to set Center of Effort apart from other wineries in the industry, as well as to attract customers and provide a sense of wonderment. Additionally, this project will showcase the capabilities of the mechanical engineering program at Cal Poly. We are Cork & Gear, a senior project team made up of five mechanical engineering students that has conducted the designing, manufacturing, and testing of the novel wine opening and pouring machine described, the "Novel Wine Opener". This document outlines the processes taken in delivering a product that satisfies our sponsor's needs.

This document builds upon the Critical Design Review (CDR) document sent to our sponsor in February 2018. Chapters from the CDR document have been updated to include relevant information regarding manufacturing and testing of the Novel Wine Opener. The appendices have also been updated to reflect the changes made since CDR. Appendices M, N, and O are new to this document and contain budget details, an operator's manual, and wiring diagrams and pinout tables.

2 BACKGROUND

During our initial background research, we focused on three main sections: customer research, product research, and technical research. Customer research involved meeting with our sponsor to obtain specifics for the project and to separate these specifics into needs and wants. Product research involved finding competitive and commercial versions of products and subsystems, whereas technical research was comprised mainly of patents, which helped us get a full view of the related technology that may help us in solving the problem and developing the wine opener. The information in this section has not changed from the Critical Design Report.

2.1 CUSTOMER RESEARCH

As part of our product research, we interviewed our project sponsor to gain a better understanding of his requirements for this project. Below is a list of his wants and needs summarized from the initial interview and emailed questions (full sponsor interview notes in Appendix A):

- Can open any of the Center of Effort's main wine bottles
- Cut and remove foil capsules on bottles
- Can remove corks from the Center of Effort's main wine bottles
- Can pour a glass of varying size (tasting, American, European) accurate to within 5%
- Able to pour multiple glasses by removing the wine glass and adding another one
- Able to handle varying glass weights/sizes
- Can be operated without access to power
- Should be transportable by 1 to 2 people
- Match branding and keep customer's attention
- Wine does not run through any tubes (pouring spout okay for better accuracy)
- Operate in less than 90 seconds
- Should be mechatronic in nature
- Mechanical corkscrew
- Wine label should be visible during device use
- Fit on table top
- Safe

A full list of customer specifications can be found in Appendix B.

2.2 PRODUCT RESERCH

During product research, we found similar products and evaluated them on their function as compared to the requirements of our novel wine pouring machine. Each product described is separated by its component that is most useful to our design.

The only true competitor to this project is Rob Higgs' wine pouring kinetic sculpture (Figure 2.1) This machine is a completely crank-powered and gear-driven kinetic sculpture that removes the cork from a wine bottle, ejects the cork from the corkscrew, and pours a glass of wine. Our device will have electromechanical components that will completely automate the process, in addition to cutting and removing the foil from the bottle.

FIGURE 2.1. ROB HIGGS KINETIC SCULPTURE

2.2.1 POURING PROCESSES

Wine Verser

This simple yet functional design shown in Figure 2.2 is an automated, cantilever bottle-holding device that can accommodate all bottle diameters and heights (Bishel). It senses when a glass is present on the machine and pours a half or full glass depending on the chosen setting. Additionally, the machine incorporates a user-friendly program that gently shakes the bottle to inform the user that the machine is awake or when the bottle is nearly empty. The Wine Verser incorporates an attachment spout that allows the wine to flow smoothly out of the bottle and into the glass without splashing. Simple switches for both power and selecting a pour size are incorporated as the main electronic components.

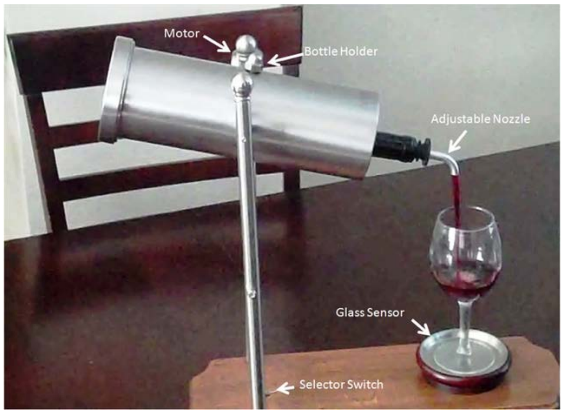


FIGURE 2.2. WINE VERSER AUTOMATIC POURER

FIGURE 2.3. POURSTEADY DRIP COFFEE POURER

Poursteady from Liberty Coffee

The Poursteady machine shown in Figure 2.3 was developed as an automated replacement for the coffee drip pouring process (LifeStyleFancy). It has the capability to pour several cups at once with a one-button system and utilizes a rotational pouring process. This unique method of automated pouring helps expand our range of potential pouring processes.

Industrial Robotic Arms

There are several KUKA brand robotic arms (Ravensburg-Weingarten; Figure 2.4 below) working with beer bottles that are programmed to remove the cap, tip the glass, and invert the bottle to pour the beer. The automated arms allow for precise and graceful movements, which is the type of aesthetic that we are aiming for. Similar robots that are not made by KUKA perform very similarly, although none of these robots deal with removing a cork. Other brands of robotic arms, such as the "Tipsy Robot" (Stapleton) shown in Figure 2.5 (left) and the Disney robot (Brandi) shown in Figure 2.5 (right), perform similar functions. The "Tipsy Robot" prepares a variety of cocktails while the Disney robot pours wine, (using a pouring spout) but is not capable of opening the bottle.

FIGURE 2.4. KUKA BEER SERVING ROBOT ARMS

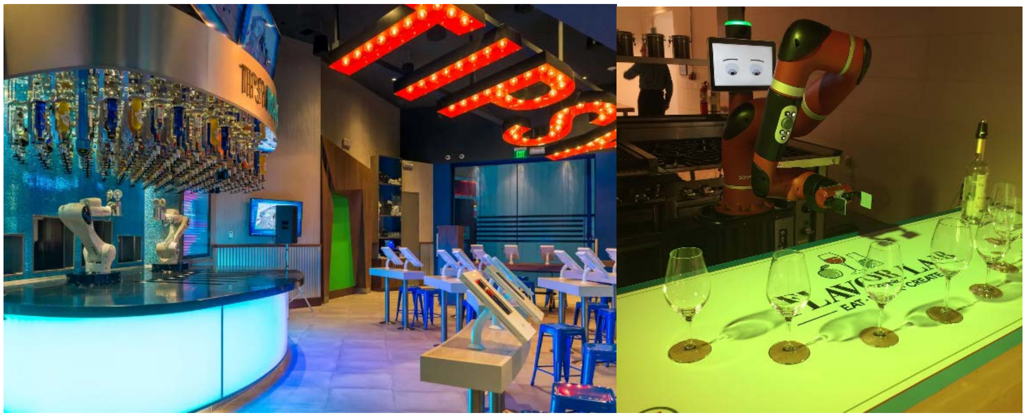


FIGURE 2.5. OTHER INDUSTRIAL ARM ROBOTS

<u>Pouring Wine using Tubes</u>

The ancient "Robotic Servant of Philon" statue in Figure 2.6 is one of the oldest known robots created (Holloway). It features a maid holding a jug of wine in one hand with her other hand extended out to hold a glass. Within the statue is a system of containers, tubes, air pipes, and winding springs which control air pressure, vacuum capabilities, and subsequently the transfer of wine, from jar to glass, by weight.

FIGURE 2.6. "ROBOTIC SERVANT OF PHILON" WINE POURER

FIGURE 2.7. D-VINE WINE MIXER AND POURER

Several other machines also use systems of tubes and gravity/pressure to pour alcoholic beverages out of decorative containers. The most competitive product on the market is the "Wine Keurig", otherwise known as D-Vine, shown in Figure 2.7 (Matt). The D-Vine has a user-friendly interface and a modern look. Although the D-Vine does not open the conventional glass wine bottle and remove the cork, it does dispense various types of Keurig-bottled wine in specially made plastic bottles to fit the machine. Consequently, these special bottles must be purchased from Keurig, are expensive, and limit the wine options to only those that the company chooses to bottle.

2.2.2 Cork and Foil Removal Processes

<u>Corkscrew-Based Removers</u>

As seen in

Figure 2.8 and Figure 2.9 below, there are many new iterations of the conventional corkscrew and twist removal process, which feature stabilizers and electronic adaptations that we can implement in our design.

Figure 2.8 (Famili) is a combination of a manual foil remover and an electric cork remover. The electronic components in this device may be a useful addition to our product. The product in Figure 2.9 (WineStuff) is a more simplistic cork remover that only automates the step of inserting the corkscrew into the cork. With both products, the rim of the bottle is attached to the device which helps in guiding the corkscrew through the center of the cork, minimizing corkscrew location error.

Figure 2.8. Electric Cork Remover and Foil Cutter

Figure 2.9. Screwpull Cork Remover

2.3 TECHNICAL RESEARCH

For the technical research of this project, we met with a research librarian on in the Cal Poly Library who helped us develop a list of related patents. Many of these patents are not directly related to our project but may have a mechanism that can be modified to fit our design or provide inspiration during the ideation process. The list of patents accompanied by a description and sketch of each, if available, have been included in Appendix C.

3 OBJECTIVES

The Center of Effort winery currently lacks a unique attraction to set apart their tasting room experience from the rest of the industry. Instead of using manual wine openers, Bill Swanson, the owner of Center of Effort, would like a decorative, automated, mechanical device to open and pour wine. The device must remove foil from variously shaped wine bottles, remove multiple types of corks, and pour a variety of volumes of wine. The device should be quick and easy to use, match the modern aesthetic of Center of Effort's new tasting room, and attract and entertain customers.

The boundary diagram shown in Figure 3.1 gives a visual representation of the scope of this project. The blue dotted line is drawn around only the things that we have control over. It excludes those that we do not. The objects that are sitting on the outside edge of the blue dotted line are the things that must be accounted for when designing our product.

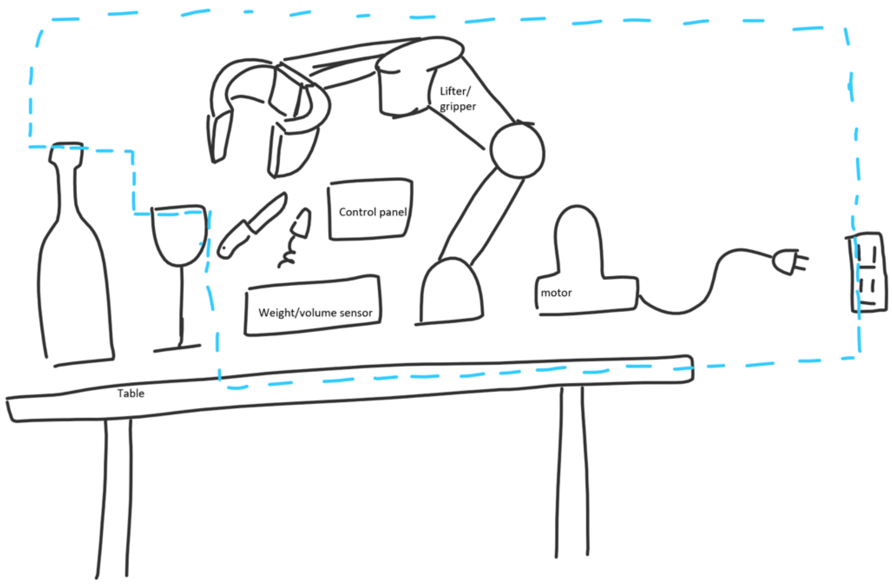


FIGURE 3.1. BOUNDARY DIAGRAM ILLUSTRATING SCOPE OF PROJECT DESIGN

Starting from the bottom of the diagram, we will design the base on which our product will reside, but we will not be able to control the table, or location of the table, that the base sits on. The motor shown in the diagram is the representation of the actuator and power source that we do have control over, which will account for the potential use of a wall outlet but will not solely rely on it.

On the left side of the diagram, the wine glass and bottle are sitting on the outer edge of the blue dotted line because we cannot modify these aspects. We will be working with several different shapes and sizes of wine bottles, wine glasses, and corks, so the product will have to be designed to account for the variety of objects that it will work with.

The components that we do have control over include the cutting device that we will use to slice and remove the foil, the corkscrew that will be used to remove the cork, the control panel, the sensor for the volume of wine poured, and the lever arm that lifts the bottle of wine along with the motor that will power each component. Each of these components is within our scope so we may choose and modify them in any way that will result in meeting the design requirements.

3.1 DESIGN CONSIDERATIONS

After collaborating with our sponsor, our project group separated each design consideration into either the "needs" or "wants" category by deciding which specifications are necessary to deliver a successful project, and which specifications would simply improve the overall product, but would not render the product unsuccessful if not incorporated.

Regarding the geometry and ability to transport the device, this product will reside on a tabletop in the Center of Effort tasting room and will only be moved in the case of a wine event. For this purpose, the product will be able to sit on a flat, smooth surface and be able to operate, assuming that the surface is level. The product will be made to fit through a standard size doorway as well as fit into a standard size car trunk for ease of transportation. Additionally, the product will be designed so that two people or less will be able to transport it. It will not be guaranteed to be transportable by a single person as it may limit the capabilities of the product.

The product will not always have access to a wall outlet, so it will run off of a rechargeable battery. It will also have the capability of being plugged into a wall outlet for continuous use in the tasting room. The battery will last long enough for the device to open at least 12 bottles of wine and complete 150 separate pours. We expect this to be a simple function of battery size. A larger battery will be used if the product does not run for the specified number of uses.

Our product will not be designed to hold or maintain more weight than the Center of Effort's heaviest bottle of wine. Our project team will measure each type of bottle and perform the necessary engineering calculations to come up with an appropriate lifting force. The lifting force will be designed with a factor of safety to be sure that it will not drop any bottles.

The staff members of the Center of Effort winery will be the only personnel operating this machine after receiving training. However, the machine may be accessible to untrained personnel at wine events and will therefore be designed for minimal to zero chance of injury. Additionally, the materials we use to build this product will be chosen only if they are safe to use in a food environment. We will not use any potentially harmful chemicals that will threaten the safety of those in the tasting room should they come close to come in contact with the product.

The product will consist mostly of off-the-shelf parts for easy replacement if a part should break. Each part of the product will be accessible using a screwdriver, wrench, or other generic tool that would typically reside in a handyman's tool belt. It will not, however, be guaranteed that each part will be intuitively replaceable, as there will be many components of this product working in unison. A guide for maintenance will be provided to the sponsor upon receiving the product.

We had an initial budget of $4,500 to use in the design and manufacturing of this product. The project team created a budget plan optimizing the amount we spent on each phase of the design process. This budget was initially enough to get all of the necessary components, but it did not account for replacing broken parts during testing and therefore pushed us over this limit. Our sponsor had assured our project team that additional funds could be made available, so in order to keep the project moving along, we found it necessary to secure these funds. The specifics of these troubles are discussed in further detail in Section 5.4.

3.2 QUALITY FUNCTION DEPLOYMENT

To ensure that we design for the correct problem and meet the necessary specifications of the product, we began a Quality Function Deployment (QFD) process. Our QFD chart is included in Appendix D for reference. In the QFD process, we first discussed whom the product is for and then separated our sponsor's wants and needs into items that can be quantified and items that can be qualified. The quantifiable wants and needs are those that can be systematically tested using an engineering process. The wants and needs that can be qualified by observation alone are described as design considerations and are acknowledged through our design process but are not added to the engineering specification list on our QFD chart. The qualified needs were assessed during the testing stage to determine whether the need has been met; the results of these qualifications are discussed in a later section.

Our QFD analysis yielded several interesting results. Our most important engineering specifications were the cork pull force and bottle lifting force. We expected this since both are related to the functional success of our device. Just below these two were factors related to size and portability. The finished device needs to be comfortable to use and portable for offsite events, often where electrical power will not be supplied. Our analysis also showed that low cost was negatively related to most of the other specs; in other words, nearly every area can be improved by spending more money. Although there was nothing particularly surprising in our QFD results, performing the analysis helped our team focus on critical specifications.

3.3 ENGINEERING SPECIFICATIONS AND RISK ASSESSMENT

Table 3.1 on the following page lists the engineering specifications that we tested. For Critical Design Review, we concluded that the lifting force was the engineering specification that would be the most difficult to meet. Some specifications that were considered high risk during Preliminary Design Review were reassessed. Changes to the specifications table between PDR and CDR are indicated with strikethroughs and are explained later in this section.

The lifting force was the highest risk specification requiring larger amounts of analysis and testing because the lifting force not only has to lift the bottle of wine, but also tilt the bottle to allow the wine to flow out in a steady fashion. Steady movements were our main concern with the lifting force to avoid spilling the wine. Finding an appropriate gripper that could vary in radius and keep the bottle from slipping was selected in the ideation process.

Table 3.1. Engineering Specifications

Spec #	Parameter Description	Requirements or Target	Tolerance	Risk	Compliance
1	Product Width	36 inches	Max	L	I
2	Product Depth	48 inches	Max	L	I
3	Product Height	2.5 feet	± 1.5 feet	L	I
4	Product Weight	25 lbf	± 20 lbf	~~M~~ L	A
5	Cork Pull Force	9 lbf	Min	~~H~~ L	~~A, T~~ I
6	Lifting Force	4 lbf	Min	H	A, T
7	Operation Time	90 seconds	Max	M	T
8	Noise Measurement	70 dB	Max	L	~~T~~ I
~~9~~	~~Change in Wine Temp~~	~~0 °F~~	~~± 2 °F~~	~~L~~	~~T~~
10	Volume Accuracy	5 ounces	± 5%	M	T
11	Battery Life	12 cork removals and 150 pours	Min	L	A, T
12	Cost	$4,500	Max	M	A

The change in risk for product weight decreased from a medium risk to a low risk because with the design more solidified, it was highly unlikely that the product itself would weigh more than the original specification: the maximum weight being 45 pounds.

The cork pull force was considered a high-risk specification during PDR but was changed to low-risk due to the design of the product. The pull force is contained within the electric corkscrew selected for the current design: the corkscrew uses its own housing to provide the resistance force needed to pull the cork. Therefore, the pull force was not something that our team needed to design a specific part for, and it was not considered in the testing phase. These reasons also explain the change in compliance from analysis and testing to inspection only. As long as the cork was fully removed, the cork pull force would be ignored.

The noise measurement compliance will no longer be specifically measured. Our sponsor indicated that he would like to be able to have quiet conversation in the room while the machine is running. Because of this, the noise was measured purely by inspection. The team did not deem it necessary to add additional sound proofing components based on this inspection. The change in wine temperature was also considered negligible because the wine bottle is not kept near any direct heat source and the temperature of the wine will not change a noticeable amount from the time that it is opened to the time that the wine is poured.

4 CONCEPT DESIGN DEVELOPMENT

The scope of this design requires successful performance of multiple actions: removal of foil, removal of cork, gripping of wine bottle, lifting and pouring of the wine bottle, and sensing pour volumes. Control of these actions should be accessible through a user interface, and all actions should successfully integrate with one another. To develop the conceptual design of this automatic wine opener, we began with ideation of individual actions.

4.1 CONCEPT DEVELOPMENT & SELECTION

Cork & Gear spent multiple weeks performing a variety of ideation exercises to come up with creative ideas that have potential to perform one or more of the necessary actions. Methods included team brainstorming utilizing a white board, sticky notes, and a projector. For brainstorming with a white board or sticky notes, each team member was provided a white board marker or a stack of sticky notes and a pen. Team members were encouraged to add any and all ideas to the board at any time during the session. Using a projector for brainstorming required verbally describing an idea one at a time so that the idea could be displayed on the projector through a single computer.

The marker and white board method proved to be the quickest method to produce the largest quantity of ideas. As a team, we held back on criticizing any ideas, because what might be considered a bad idea often led to the development of a great idea. This effect was amplified when we brought in friends that were much less familiar with the constraints of the project to help brainstorm. The people with outside perspectives came up with ideas that our team may not have thought of due to the increased familiarity with the scope of the project.

After many ideas were generated for each of our six functions, we began to refine each list toward a single concept in several stages. A first pass was taken to quickly remove ideas that were infeasible, unsafe, or outside of our scope. Then, in every list, we developed sets of criteria for comparing concepts in a Pugh matrix. Once each member had time to evaluate the concepts individually, we came together to discuss which ideas to move to the next stage with and which ones to drop. This analysis was helpful in identifying critical design features in some areas. The following sections provide descriptions of the remaining ideas for each concept.

4.1.1 GRIPPING

The focus for gripping the bottle rested on two different automated grippers that could grip the wine bottle with enough stability to complete the lifting and pouring actions of the device. One claw is shaped like a pincer (Figure 4.1), while the other is purely linear (Figure 4.2). A proof-of-concept prototype of the linear gripper is shown in Figure 4.3.

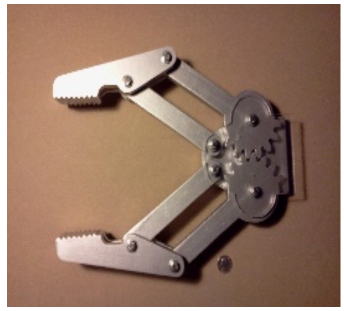


FIGURE 4.1 PINCER GRIPPER

FIGURE 4.2 LINEAR GRIPPER

FIGURE 4.3 CONCEPT PROTOTYPE OF LINEAR GRIPPER

Static gripping devices were also considered. These devices require the user to snap the bottle into place as with wall-mounted broom clips (Figure 4.4). Similarly, one idea involved a wine bottle handle that would be attached before placing the bottle into the machine (Figure 4.5). One of the main factors in this selection was the ability to grip various shapes and sizes of bottles.

FIGURE 4.4 BROOM CLIP

FIGURE 4.5 BOTTLE HANDLE

4.1.2 FOIL REMOVAL

Many of the ideas developed for removing the foil involved a knife coming into contact with the wine bottle from the side of the bottle neck or on the top of the bottle. There were few concepts better than the commercially available cutters (see Figure 4.6Figure 4.6) that surround the cap, so our final choices all involved adapting a cutter from an existing product to our design and automating it. These choices were mainly due to the wide availability and reliability of commercial foil cutters at cutting a wide range of existing types of foil.

FIGURE 4.6. EXAMPLES OF CHOSEN FOIL CUTTING CONCEPT

4.1.3 CORK REMOVAL

Since a traditional corkscrew removal was requested by the sponsor, the top methods of cork removal included a traditional pull corkscrew, a Waiter's Helper corkscrew, a Rabbit corkscrew, and an electric corkscrew. Examples of each corkscrew are shown left to right in Figure 4.7 below.

FIGURE 4.7. CORKSCREW CONCEPTS

4.1.4 LIFTING & POURING

The lifting and pouring function comprises the largest physical portion of our design, as it requires the most movement; we found that our preferences gravitated towards smaller and simpler concepts. One potential idea shown in Figure 4.8 was a type of "escalator" in which the wine bottle is placed on a conveyor track, lifted upwards on an angle, and tilted over a point to pour the wine.

FIGURE 4.8. CONCEPT PROTOTYPE OF ESCALATOR LIFT/POUR

Figure 4.9 shows a "C" track in which the bottom of the wine bottle is placed onto a curved vertical track while the neck of the bottle rests on a pivot point located above the wine glass. The bottom of the wine bottle would be pulled up along the track, thus increasing the tilt angle and pouring the wine into the glass below.

FIGURE 4.9 CONCEPT PROTOTYPE OF C TRACK LIFT/POUR

The four-bar linkage device shown in Figure 4.10 is a motor-driven system which lifts the bottle up and tilts it to pour wine into a wine glass. The wine bottle is attached to the four-bar linkage with a hose clamp or other attachment method.

Figure 4.11 shows the prototype for a gyroscope idea that would secure the center of a wine bottle and rotate it accordingly to pour the wine into the glass.

FIGURE 4.10 CONCEPT PROTOTYPE OF FOUR-BAR LINKAGE LIFT/POUR

FIGURE 4.11 CONCEPT PROTOTYPE OF GYROSCOPIC LIFT/POUR

The last major lifting and pouring idea used three simple motions: linear vertical motion, linear horizontal motion, and rotation. The linear motions would lift and move the wine bottle, and the rotation motion would tilt the wine bottle to pour it into a glass.

4.1.5 SENSE POUR VOLUME

The top ideas for sensing the amount of wine poured include load cells, strain gauges, and pressure sensors. Less technical methods involved using a scale, a mechanical pour regulator, a timer and measuring flowrate. These methods were eliminated due to inaccuracies or complexity of the measurement or design.

4.1.6 USER INTERFACE

Brainstorming provided a large range of user interface options including mechanical levers, switches, dials, buttons, a touchscreen, a phone app, or a remote control. The sophistication of the user interface will be largely based on the amount of time the team has available after completing the design of the rest of the product.

4.1.7 Overall Design Integration

To successfully open and pour a bottle of wine, all of the actions described above must work together. Three ideas were compared for the overall integration. One idea involved stations in a linear setup. Another idea placed stations around a rotating platform. The third idea utilized one main arm with multiple tools. The arm would be able to rotate different tools over the wine bottle so multiple actions could be performed without moving the bottle.

The Pugh matrix analysis that compares the ideas for each function confirmed our expectations of which ideas would be most appropriate for the project, such as the use of a motorized corkscrew. Although the exact method was still undecided, it was confirmed that the amount of wine would be weighed rather than using a less direct method of determining the volume. With a smaller selection of ideas, a weighted decision matrix was built for each function using the concepts that had passed our Pugh matrix analysis. The criteria for the weighted decision matrix were drawn directly from our engineering specifications and customer needs and wants list and were given weights based on each criterion's significance in the design. The top idea for each function was chosen and an alternate idea was chosen for those functions that proved to have several ideas of similar suitability. The results of our decision matrix analysis are summarized in Table 4.1, and the full weighted decision matrix for each concept can be found in Appendix E.

4.2 PROTOTYPING

4.2.1 Concept Prototypes

Following completion of analysis, we began prototyping the best options of each function produced by the decision matrices. Although the best options had been decided for each function, only the lifting, pouring, and cork removal functions were prototyped. These functions were chosen for prototyping because they had more challenges in terms of functionality and were the basis of one or more of the other function. Material availability also played a factor in choosing the early prototypes.

4.2.2 Proof-of-concept testing

Initially, our team decided that the four-bar linkage idea would be the most appropriate method for lifting and pouring the wine. The first prototype of this simple model was made from foam core. Once the dynamics of the system were further analyzed, a sturdier version was built using laser cut plywood as shown in Figure 4.12. A hobby-grade servo motor powered the linkage system and gave us a better idea of the motion the bottle would have.

TABLE 4.1. LEADING CONCEPTS FROM IDEA CONVERGENCE

FUNCTION	LEADING CONCEPT	ALTERNATIVE
GRIPPING	Broom clip	Bottle Handle
LIFTING & POURING	Four-bar linkage	Rotating platform with stations
USER INTERFACE	Mechanical switches	-
FOIL REMOVAL	Cap cutter	-
CORK REMOVAL	Electric corkscrew	-
SENSE WEIGHT	Pressure sensor	Load cell

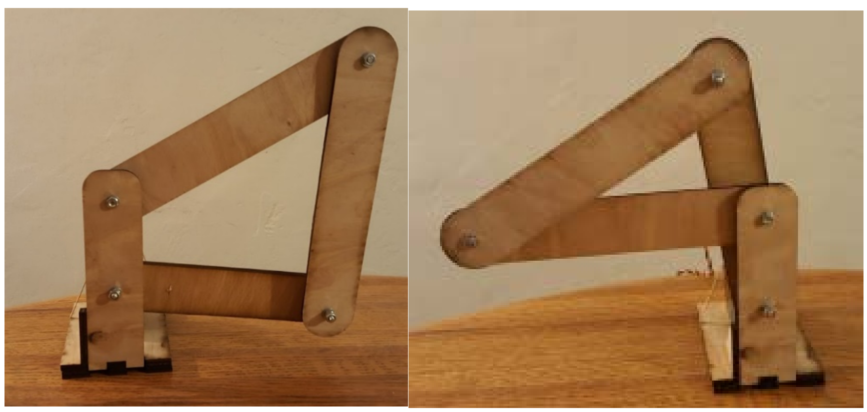


FIGURE 4.12 FOUR-BAR LINKAGE PROTOTYPE

The second proof-of-concept prototype was the uncorking tower. An electric corkscrew was purchased for this prototype and integrated into a mechanical frame. This structure included the attachment to the electric corkscrew, the tower that secured the linear actuator, and the base as shown in Figure 4.13. All of these components were also laser cut from plywood. The prototypes helped prove that we could remove the cork and pour its entire contents.

4.2.3 RESULTS OF CONCEPT TESTING AND REDESIGN

After the Preliminary Design Review, testing and analysis of the pouring function continued until it was clear that there were more downsides to the design than we had originally anticipated. There is "slop" involved with the linkage design that may reduce accuracy over time. Additionally, the four-bar linkage provides a motion that does not keep the mouth of the bottle in a steady location. This is an issue that would likely cause a significant amount of spilling and would be difficult to account for in the design while keeping the other components in mind.

FIGURE 4.13 ELECTRIC CORKSCREW PROTOTYPE

Due to the difficulties of the four-bar linkage, we went back to our foam core prototypes and decided that a simple lift and pour method would be easier to design and implement. Additional brainstorming led us to the idea that we have chosen to move forward with.

4.3 CHOSEN CONCEPT QUALIFICATIONS

The overall concept that we chose incorporates only the original cork removal prototype that we developed. A design allowing accurate pouring and minimal spilling were the main focuses for this decision. Bottle pour angles were experimented with, and a summary of these tests and calculations can be found in Appendix F. Programming the device itself would prove to be one of the biggest challenges. Experimenting with the programming was necessary to get the motions down correctly. Thorough testing was performed to verify the functionality of the product as a whole.

The chosen concept already fits many of the specifications discussed in Chapter 3. The product fits through a standard doorway and into the back seat of a small sedan. Transportability was an important goal in this project, as the device will be taken to wine events. The preliminary estimate for the product weight was 45 pounds maximum.

An additional aspect that made this design attractive was that very few modifications would be needed in order to open and pour various types and sizes of bottles. The linear actuator allows the cork and foil removal to be independent of height and bottle shape.

By limiting the range of travel that the bottle must undergo to complete each step of the process, we were able to cut down the duration of the process significantly. With this design, the bottle does not have to be moved between cork removals and pouring. After programming the motion, completing the entire operation in under 90 seconds was not an issue.

5 FINAL DESIGN

5.1 DESIGN DESCRIPTION

5.1.1 OVERALL LAYOUT

The novel wine opener performs four major functions: removes the foil from a wine bottle, removes the cork, pours the wine into a glass, and senses the amount of wine in the glass to produce accurate pour sizes. The opener is controlled by a user interface located on the front angled panel of the base. The layout of the design with all of the integrated components is shown in Figure 5.1.

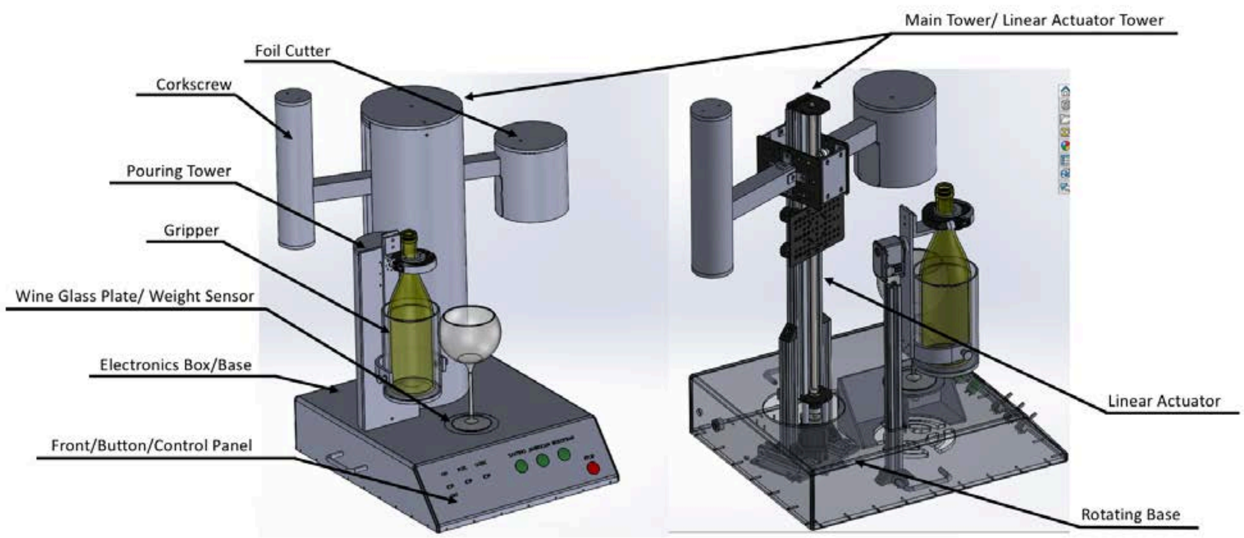


FIGURE 5.1 ISOMETRIC DRAWING OF WINE OPENER

5.1.2 SUBSYSTEMS

In order for the foil and the cork to be removed, the wine bottle must remain stationary. The bottle is held with a custom gripping mechanism in which the bottom of the bottle slides into a translucent sleeve and is secured into place with two thumb screws. A collar is then clasped around the neck of the bottle and tightened (see Figure 5.2 for components). The custom gripping mechanism is made up of several manufactured components that include a "backbone," which is the vertical bar that structurally supports the bottle and attaches to the motor. The backbone attaches to the gripper curve, which is a C-shaped bar, and a custom L-bracket, which attaches to the collar clasp to hold the neck of the bottle. The gripper curve has holes in its sides, where custom threaded inserts attach. These custom threaded inserts also attach to the acrylic sleeve on each side, allowing the sleeve to rotate. The rotating sleeve allows the bottle to be easily installed into the gripper. Thumb screws are also inserted through the threaded inserts to tighten the base of the bottle into place. Inside of the sleeve, there is a nylon convex insert that secures the punt (the dimple at the bottom of the wine bottle) into place.

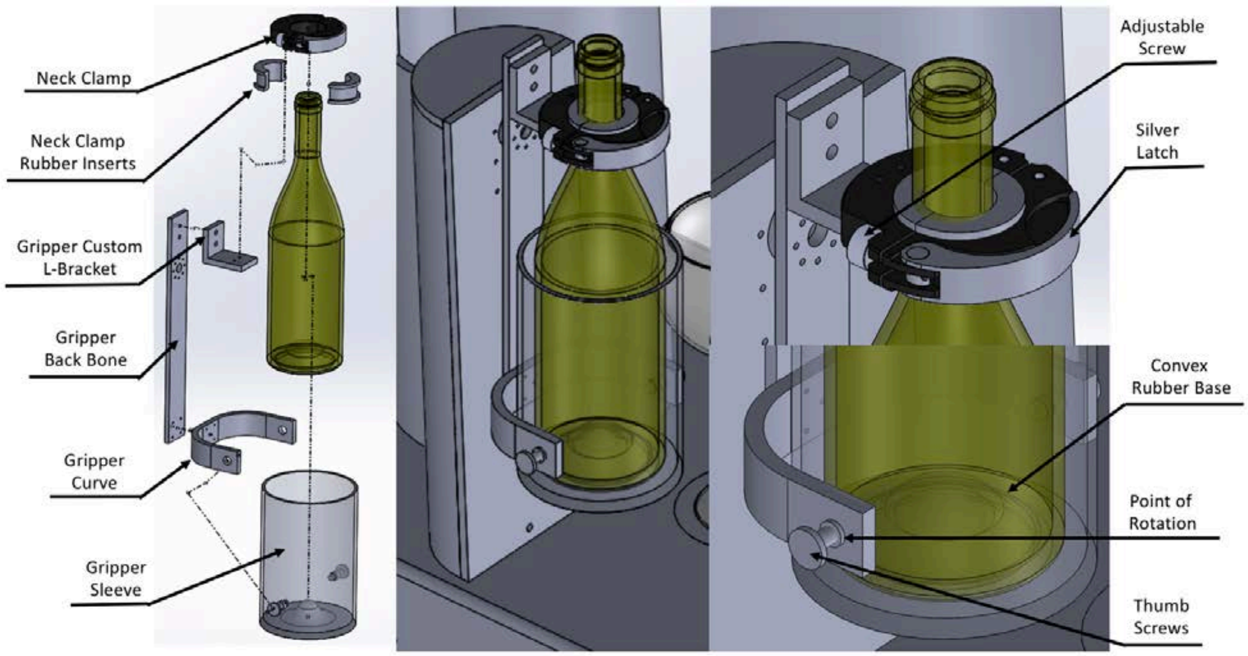


Figure 5.2 Gripper Components

The foil and cork removal functions are accomplished using the tool arms attached to the rotating tower. The rotating tower is made up of a linear actuator mounted on a turntable inside the electronics box. The corkscrew and foil cutter mechanisms are mounted on a free-floating gantry, which rests atop the powered gantry attached to the linear actuator (Figure 5.3). The purpose of the free-floating gantry is to allow the corkscrew and foil cutter to function without additional force provided by the linear actuator. The free-floating gantry also prevents unnecessary bending moments and helps account for bottles of various heights. The tower rotates to center the subsystems over the bottle and rotates them away upon completion, so they do not obstruct the pouring mechanism.

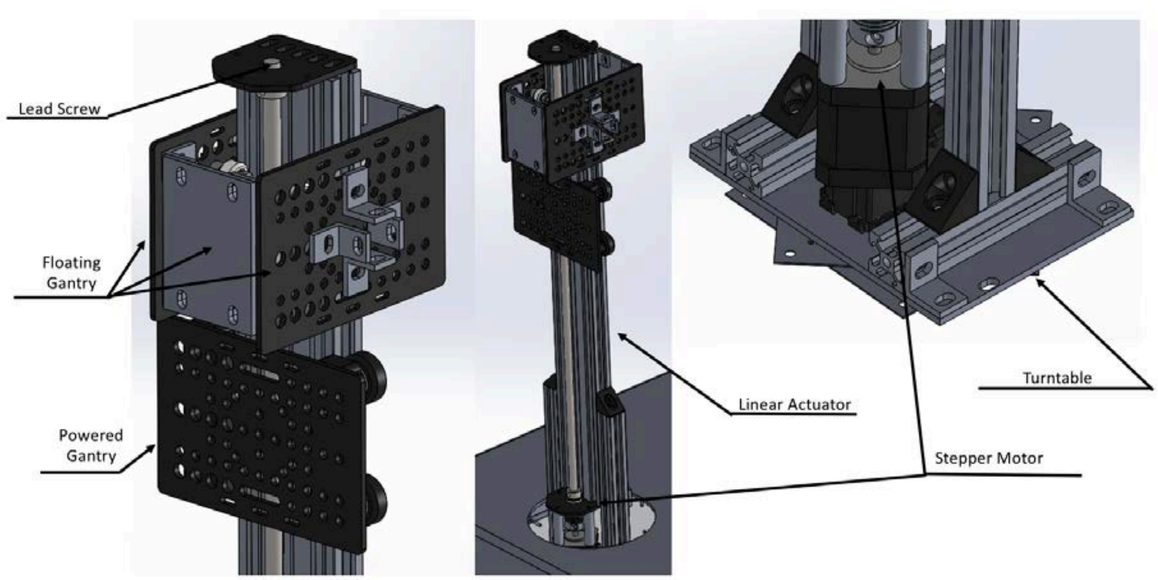


Figure 5.3 Linear Actuator Tower Components

Foil removal begins when the main tower rotates until the foil cutting tool arm is centered over the wine bottle. The linear actuator lowers the gantry system until the floating gantry rests on the top of the bottle. The foil cutting mechanism consists of two linear servos with serrated commercial foil cutter blades attached. The servos mount to a platform, which rests on top of the bottle, and squeeze the blades into the foil. Simultaneously, a servo motor rotates the platform 360° to cut the foil. Once fully cut, the linear actuator lifts the tool up and away from the bottle, removing the foil with it.

The first iteration of the foil removal design, shown in Figure 5.4, results in a cut at a fixed distance from the top of the bottle to the cut location. The top plate mounts the linear servo motors for adjusting the blades and serves as a structural backstop, thus allowing the blades to cut in the same spot as they rotate about the bottle. The blades used have serrated edges because they have been proven to be more effective than straight edged blades through the testing process.

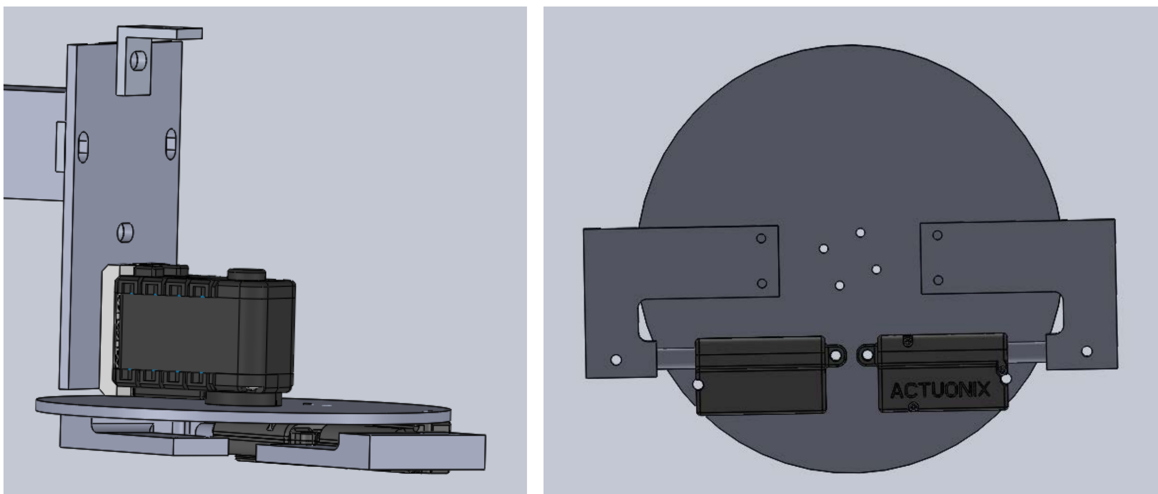


FIGURE 5.4 FOIL CUTTER DETAIL, FIRST ITERATION

The original iteration of the foil cutter got the main idea across: the two linear servos and the rotational servo would squeeze the foil and rotate to cut. However, this version needed some improvement as the brackets that held the blades were not structurally supported, giving them a lot of wiggle room, and thus did not cut the foil effectively. They would bend in the vertical direction and also out to the sides (Figure 5.5), prompting the next iteration of the foil cutter, shown in Figure 5.6.

FIGURE 5.5 FOIL CUTTER MOVEMENT, FIRST ITERATION

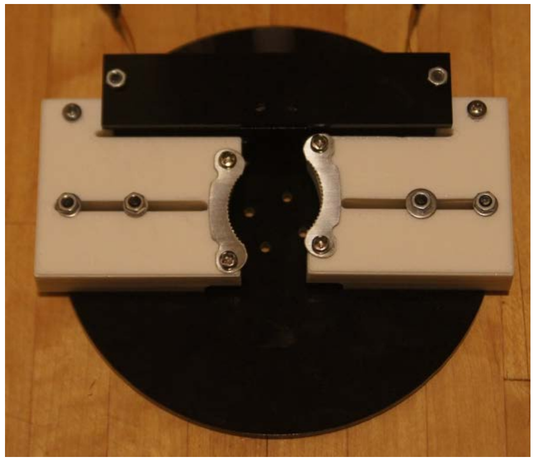


FIGURE 5.6 FOIL CUTTER, SECOND ITERATION

This version of the foil cutter stabilized the brackets vertically and horizontally by putting screws and bolts through the center of the arms, forcing it to follow the desired path. This led to much more successful force on the neck of the bottle. However, this version would get caught on the bolts quite often, preventing the blades from either reaching the bottle or preventing them from returning, making it an unreliable design. This led to the 3rd iteration shown in Figure 5.7.

FIGURE 5.7 FOIL CUTTER, FINAL PROTOTYPE

This version presents an orientation where the linear servo motors face in opposing directions, shortening the length of the brackets, and decreasing the overall size of the foil cutter. As proved by the last iteration, the stabilization of the brackets was necessary, but it had to be done in a more effective way. The round acrylic plate mounts the motors in addition to a straight bar of acrylic positioned to provide a path for the brackets to follow. The brackets are designed with a rectangular cutout as shown in Figure 5.8 for this purpose.

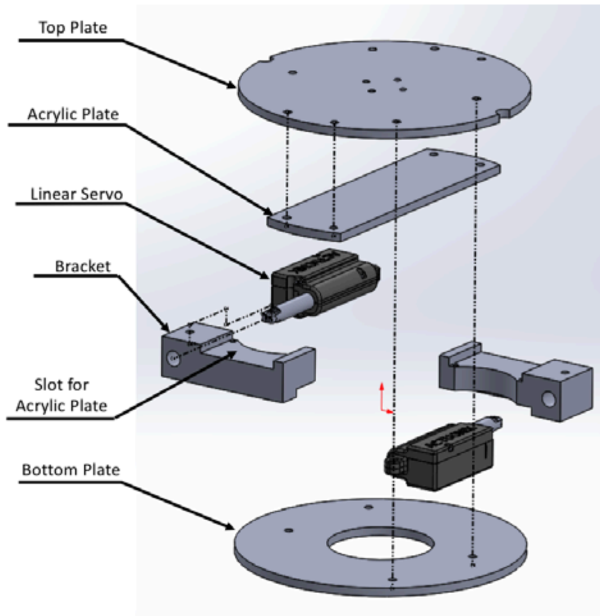


FIGURE 5.8 FOIL CUTTER, FINAL DESIGN DETAIL

Positioning the corkscrew is similar to positioning the foil cutter in that the linear actuator tower rotates the cork removal tool arm directly above the mouth of the bottle. The linear actuator lowers the tool arm until the corkscrew rests on top of the cork. The corkscrew is an off-the-shelf Houdini electric corkscrew wired to be controlled remotely. Controlling the motor with a microcontroller and using an external power supply allows us to achieve more torque by running it at its maximum voltage/current rating instead of relying solely on the battery power it uses during traditional use. Using this corkscrew removes the need to implement a pull force on the cork as was discussed previously, because the corkscrew uses its own housing for the resistance force and pushes against the bottle to remove the cork. When the electric corkscrew's full travel into the cork is completed, it continues spinning to remove the cork steadily. This corkscrew also has the ability to back out the cork from the corkscrew on its own by reversing the rotation.

Once the foil and cork are removed, the wine bottle rotates about the point at its neck where the collar clasps around it (see Figure 5.2); this point of rotation limits the horizontal movement of the mouth of the bottle, making spilling less likely. At the same neck point, a motor connects to the gripper and rotates the bottle with the entire gripper mechanism in order to pour the wine. The wine is simultaneously measured by a load cell which supports the wine glass plate shown in Figure 5.9, and provides a feedback loop to tell the pouring motor when to stop. The load cell is mounted inside the electronics base, to be concealed for aesthetic purposes. Below the wine glass plate, there are draining cutouts (Figure 5.10) to allow the wine to fall through without affecting the electronics.

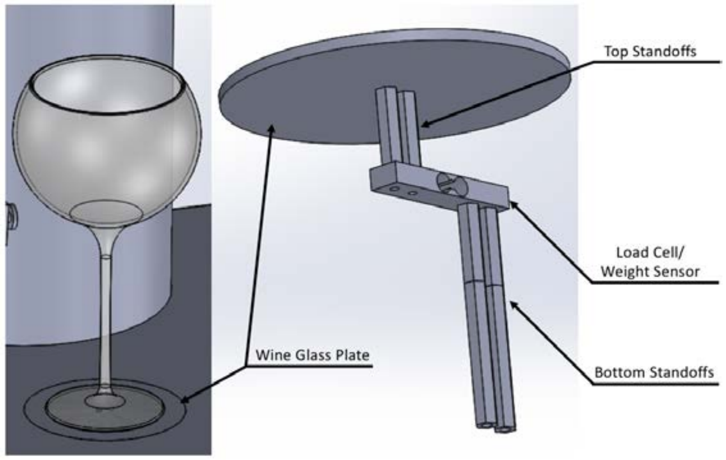


FIGURE 5.9 LOAD CELL AND WINE GLASS PLATE

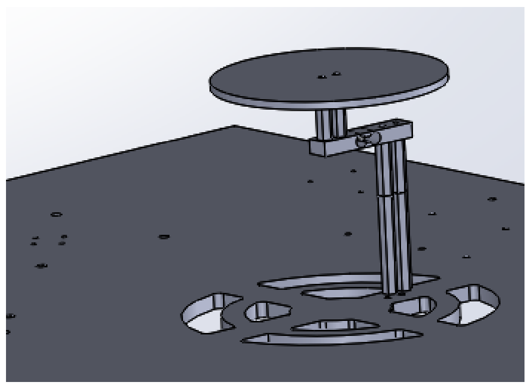


FIGURE 5.10 DRAINAGE CUTOUTS

The user interface, located on the angled panel of the base, uses toggles to initiate the foil cutting and cork removing, and uses buttons to initiate the pouring of the wine opener. Figure 5.11 shows the layout of the user interface.

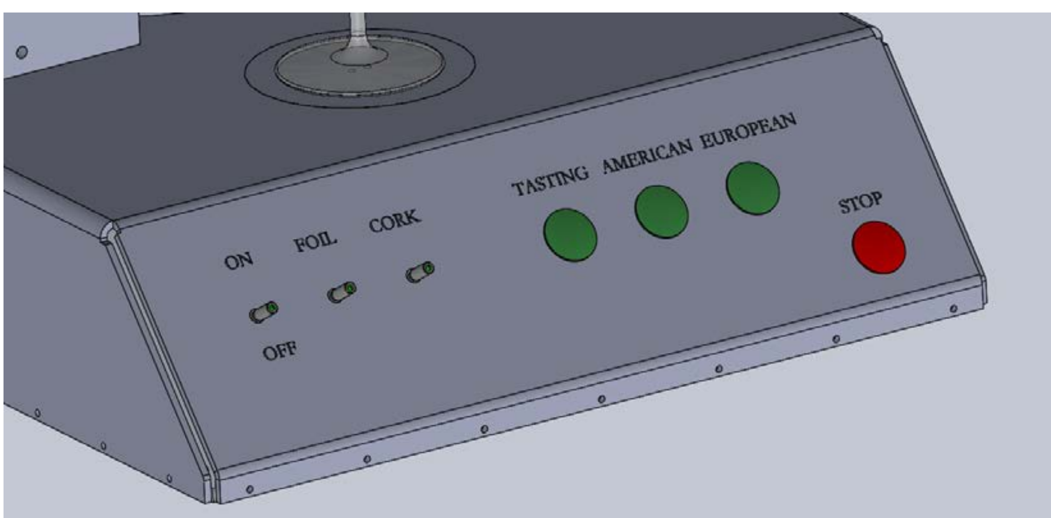


FIGURE 5.11 USER INTERFACE LAYOUT

The operation of the user interface is as follows: The user must turn the lockout keyswitch to enable power to the machine before initializing the microcontroller and the motors using the power toggle on the front panel. The cork and foil toggles can be switched on to indicate which functions the user would like to take place. If both are off, the machine will simply pour the wine. The pour size buttons function as the start button for that pour; the machine will start will the cork and foil functions if the toggles are on before proceeding to the pour. If at any time the machine starts to malfunction, the emergency stop button labeled "Stop" can be pressed to allow the machine to slowly return to a safe position and power off. The user must then switch the power toggle off and on again to continue operation. For more detailed information on how to run the machine, an operator's manual has been provided and can be found in Appendix N.

5.1.3 ELECTRICAL SYSTEMS

Our device will be actuated mechatronically with a network of servo motors, sensors, control boards, and a microcontroller. The Arduino Mega is our controller of choice, since many hardware and software solutions already exist for it. Smart servos are used for all motion except the corkscrew and main tower, where precise position or velocity control is not necessary. A load cell measures the volume of wine poured, and mechanical switches register user inputs.

The load cell, two rotational servos, and stepper motor all interface with our microcontroller through intermediate driver boards. We designed a custom circuit board to assist in routing power and data cables (Figure 5.12). The pouring motor interfaces to the Arduino through a tri-state buffer chip, seen on the right side of the board in the below image. A carrier board for an A4988 stepper motor driver chip (the green board) plugs directly into this board as well. The linear servos in the foil cutter are the only motion elements connected directly to the Arduino for control but pass through the board to support a standard three-pin servo header.

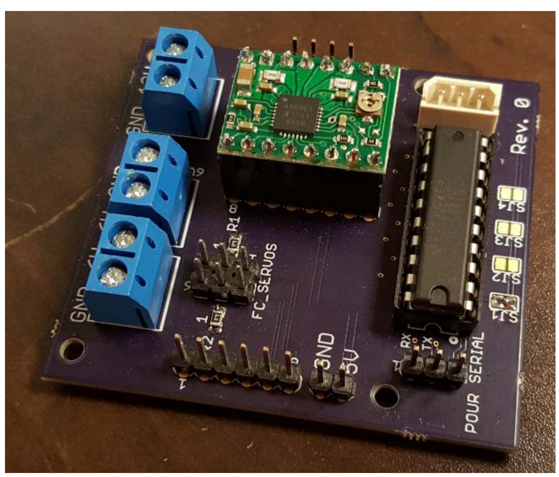


FIGURE 5.12. CUSTOM CONTROL BOARD

The corkscrew is driven by a VNH5019 DC motor driver chip, which provides a simple interface to run the screw in both directions. It also features PWM capability, but we drive the corkscrew at the full 6 volts that it was originally designed to run on.

All of the user interface switches plug directly into digital input pins on the Arduino. The LEDs are controlled separately on 12-volt power. The toggle switches use a synchronous circuit, meaning that they turn on when the switch is in the "on" position. This makes it easy to tell when a specific feature has been selected, or when the main controller power is on. The button LEDs are connected to a power relay board which is driven by the Arduino. This allows the LEDs to be switched on and off independently of button presses, which is useful for displaying status information.

The whole device will be powered from an external 12-volt supply, using a 5.5mm barrel jack connector. This allows us to use commercially-available power supplies and batteries in our design, fulfilling specification #11 in Table 3.1 The foil cutter requires a small subsystem on 6 volts, but inexpensive and reliable step-down converters exist for this purpose. The Arduino additionally regulates its own 3.3-volt and 5-volt supplies for sensors and data. Figure 5.13 provides an overview of the power and data connections between our primary electronic components.

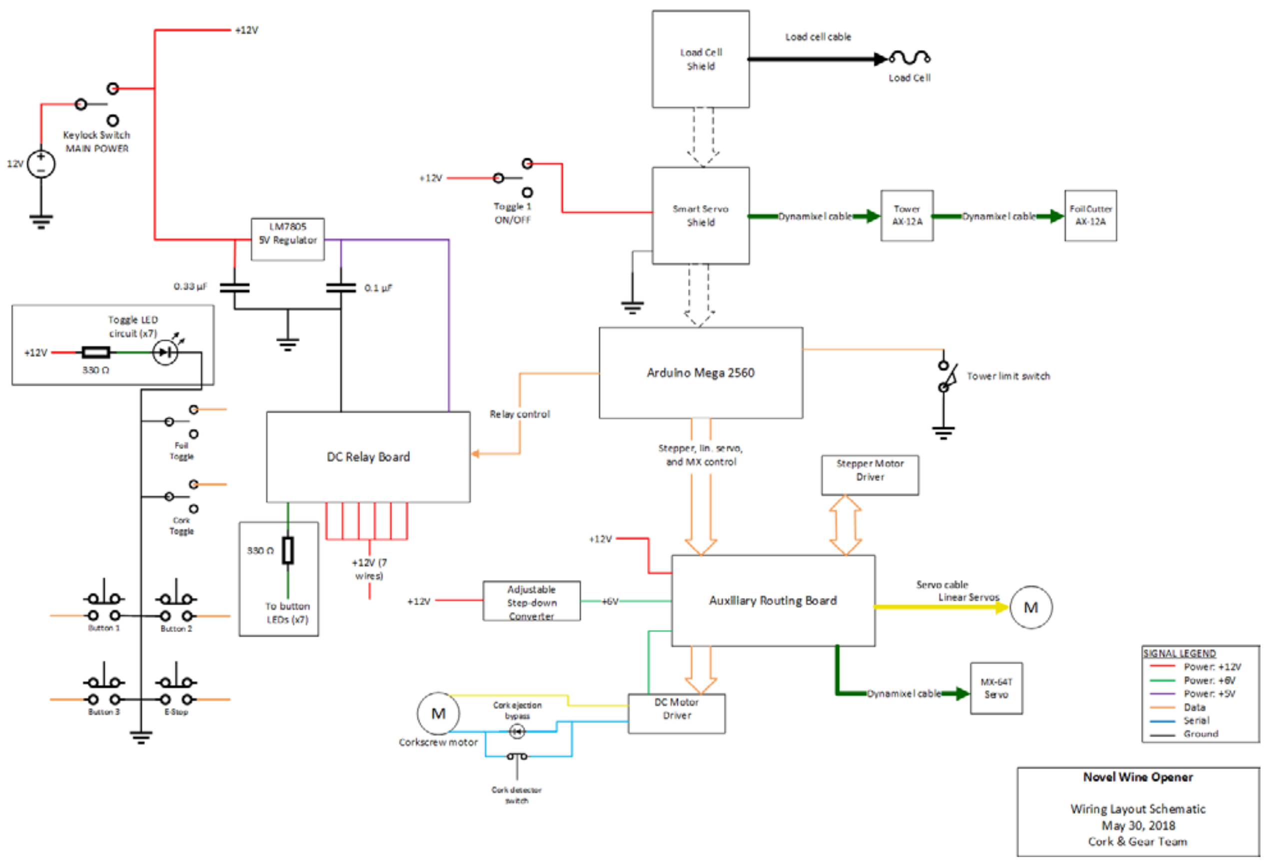


FIGURE 5.13. WIRING LAYOUT SCHEMATIC

5.1.4 SOFTWARE DESIGN

The linear nature of our tasks allows us to program the device as a simple state machine. Since we do not have multiple inputs and outputs that will be active at the same time, no multitasking code or hardware is necessary. An emergency stop switch is implemented using hardware interrupts, breaking out of the program flow at any point and putting the device into a halted state. The flowchart shown below in Figure 5.14 illustrates the primary software states.

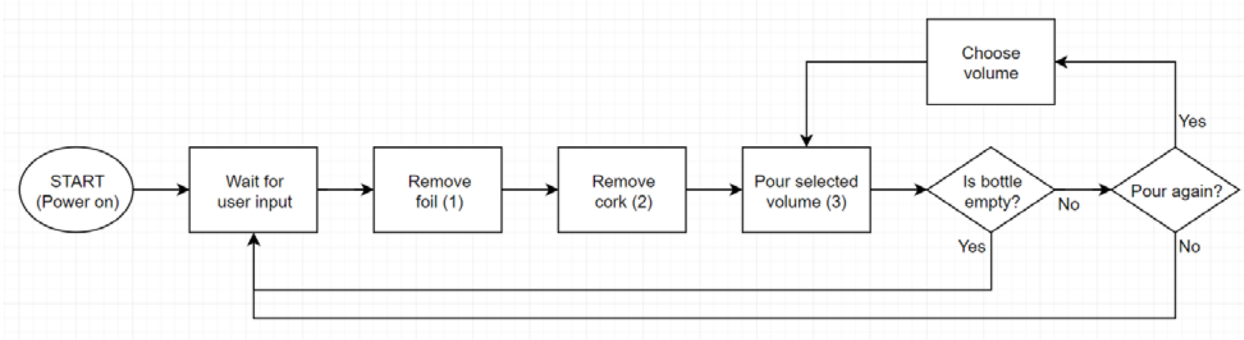


FIGURE 5.14. MASTER STATE DIAGRAM

The foil removal and cork removal states will contain many sub-states to control specific motor movements, indicated with (1) and (2) on the flowchart. Unloading of the removed cork and foil are sub-states that happen automatically during the opening process. These sub-states, along with the master state diagram and pouring controller block diagram, are all provided in Appendix G.

The pouring state, marked with (3), will take the form of a closed-loop PID (Proportional, Integral, Derivative) controller. The controller accepts a desired pour volume from the microcontroller, selected by the user, and pours an output volume into the wine glass. Involved in this system are the pouring and weight-sensing hardware (load cell); the pouring motor is given a signal to tip the bottle and pour wine, while the sensor under the wine glass provides feedback on how much wine has been poured. A digital filter was used on the data read back from the load cell as the data was too noisy, mainly because of the wine splashing in the glass, to keep the motor in steady motion. The system is capable of recording the amount of wine already poured in order to estimate the remaining volume in the bottle. Figure 5.15 shows our block diagram design for this controller.

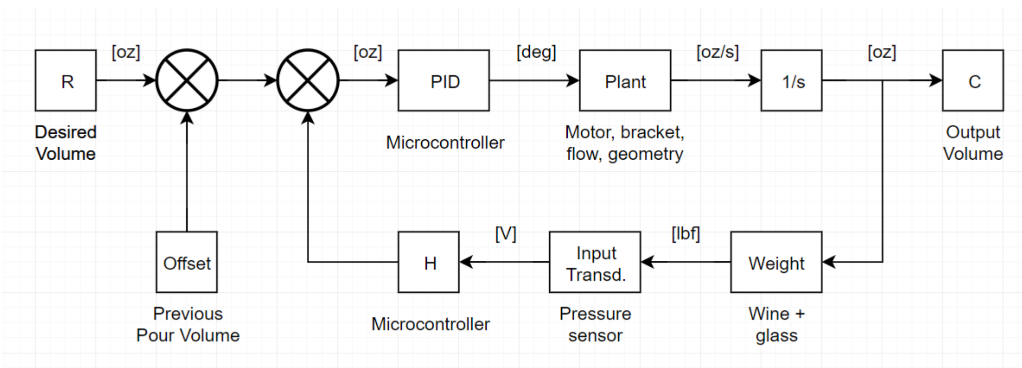


FIGURE 5.15 POURING CONTROLLER BLOCK DIAGRAM

The MX-64T pouring motor contains the PID controller. Its values can be changed by writing to the servo's registers over the serial connection. In practice, the controller actually manages the angle of the bottle based off of the pouring rate – it attempts to keep the rate consistent between a certain range by increasing or decreasing the bottle angle. For the first 90% of the target pour volume, the controller pours quickly to get the volume up. Between 90-95%, the angle limits are reduced to slow down the pour. We discovered that the best way to avoid drips was to pour slowly enough that sloshing did not occur in the bottle, then slowly bring the bottle back down. Once pouring is complete, the load cell captures the final pour weight and subtracts it from the remaining volume. This value is later used to incrementally adjust the upper pouring limit as the bottle is emptied.

Because the Dynamixel motors communicate over 1-wire serial TTL (transistor-transistor logic), a special interface such as the smart servo shield must be used. This works fine for the AX-12A servos, but the MX-64T servo uses a slightly different control table. The least expensive route to working with the MX-64T was through a tri-state buffer (such as the 74LS241N in our design), which put both the transmit and receive signals onto the same wire. The Dynamixel_Servo library, available through the Arduino library manager, was used to manage this interface, although we were unable to read data back from the motor.

Programming of the Arduino microcontroller will be carried out in C++ over the built-in USB port. This will make updating or modifying the code easy, as well as allow for the Arduino to be easily replaced. A programming guide is included with the Operator's Manual for guidance in modifying or updating the control code.

5.2 ANALYSIS AND RESULTS

The corkscrew and its housing were originally going to be manufactured by us, which required knowledge of the force needed to remove the cork. However, the design was changed to integrate a commercially-available Houdini electric corkscrew that is already designed to pull corks, removing the need for us to incorporate a pulling force into the design. Testing revealed that the corkscrew was sufficiently powerful to engage and pull every cork in our test cases.

One concern that we had during the development of the foil and cork removal operations was the tower stepper motor's ability to pull the cut foil off of a bottle, while also lifting the weight of the floating gantry. Although the forces were not analyzed, our tests showed that the stepper is more than powerful enough to pull the foils off, unless the foil is incompletely cut or scored.

The original plan to rotate the bottle was to grip it in the middle and rotate it around a central point. The original calculations for this provided a necessary torque of about 340 oz-in. However, the new design rotates the bottle around the neck, increasing the necessary torque. The new calculations assume that the bottle is 3.5 pounds when full, and that its center of gravity lies about 8 inches down from the gripping point on the neck. The gripper assembly is assumed to be about 2 pounds and to have a center of gravity 10 inches below the gripping point. All of these values were chosen to be of an extreme case, and result in a required torque of 780 oz-in. The Dynamixel MX-64T motor provides 850 oz-in at 12V. Detailed hand calculations for the required torque can be found in Appendix H.

The torque supplied by the MX-64T is sufficient for most operations, although the motor sometimes stalls at low speeds. The final gripper ended up being heavier than expected, mostly due to the steel neck clamp that we chose. A worst-case scenario would be where the bottle is both full and horizontal (location of greatest moment on the motor). When the motor stalls, the controller "lets go," and the gripper swings back down. Friction in the motor and at the pivot point keep the bottle from crashing into the glass, but it does create a pinch hazard. As a result, we built a clear plastic safety shield shown in Figure 5.16 to discourage onlookers and operators from placing their hands between the raised gripper and the pouring tower.

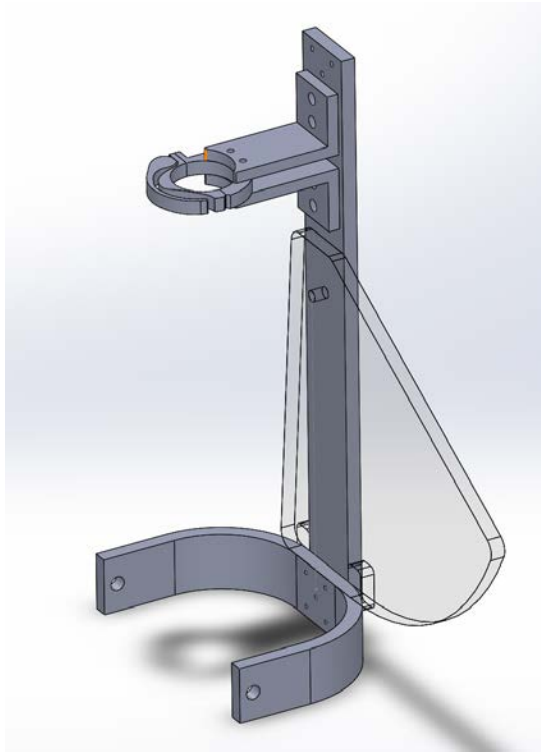


FIGURE 5.16 REMOVABLE SAFETY SHIELD

Using the motor to pour an appropriate amount of wine depends both on the angle of the wine bottle and the current amount of wine in the bottle. The pouring controller reads both the current volume and the rate of change of the volume (pour rate) and adjusts the bottle angle based on this information. The analysis suggests that wine will begin pouring just over 80 degrees from the horizontal and will finish pouring just under 110 degrees from the horizontal; this is illustrated in Table 5.1. Between these two angles, there is a linear relationship which can be seen in Figure 5.17. The complete datasheet is located in Appendix F.

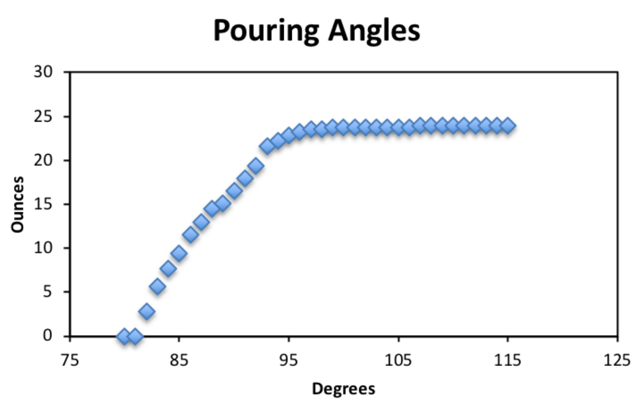


FIGURE 5.17 POURING ANGLES

TABLE 5.1 POURING ANGLES

Angle [degrees]	Approx. Percent of Bottle Poured (Average)	Average Total Bottle Content Poured [oz]
82	0%	0.00
84	25%	5.60
87	50%	11.50
92	75%	17.95
96	95%	22.85
108	100%	23.99

We implemented a rudimentary proportional controller using the pour rate as the input signal, and using the volume reading as the cutoff trigger. We opted not to develop a full PID controller partially due to the increased complexity, and partially due to difficulties in accurately working with the motor and load cell. The final revision of this controller features a number of tunable parameters and provides a repeatable error of ±10%. This does exceed our original specification of ±5% error, however. Potential ways of reducing this error in the future is discussed in a later section.

5.3 COMPONENT, MATERIAL, AND GEOMETRY SELECTION

Each of the wine opener functions incorporate purchased and custom manufactured parts. Commercially available parts have been used where possible, and simpler features were chosen to keep manufacturing time to a minimum.

V-slot beams and ¼" aluminum plates are used throughout the design as structural materials. V-slot is used as the main support for both towers in our design as well as the tool arms. Our team chose this material for its strength and versatility in prototyping. Waterjet-cut aluminum plates are used for adapting V-slot to other components as well as the electronics housing. This material was chosen for appearance, weight, and simplicity of manufacturing. Additionally, we were able to model and prototype these parts with inexpensive laser-cut acrylic sheets.

The two main components of the rotating tower are a linear actuator from OpenBuilds and a Dynamixel AX-12A smart servo located in the base. The linear actuator was selected because it is tall enough to lift the components above the wine bottle and sturdy enough to lift both components. The OpenBuilds part system is also easy to modify and integrate with the rest of our design. The smart servo was chosen for its positional control, which is crucial for aligning tools with the wine bottle.

The foil cutter consists of four unique systems. These systems include a smart rotational servo, a pair of linear servos, custom manufactured blade holders, and serrated cutter blades. The frame and housing are made from 1/4" aluminum plate and pipe. The servo motors were selected for their positional control as well as their overcurrent protection. The smart servo is the same model as the tower rotation servo mentioned above, simplifying the control hardware and software. In order to attach the blades to the linear servos, special blade holders are required due to the unique mounting pattern on the linear servos. For our structural prototype, these holders were made from plastic on rapid prototyping machines. The holders in the final prototype were outsourced to be printed from high-strength nylon. The cutter blades were taken from an existing foil cutter, chosen for their effectiveness and ease of replacement.

The corkscrew system features an electric corkscrew and a custom mounting bracket. The corkscrew is a commercially-available model that has been tested and proven to work. An aluminum housing secures the corkscrew to the gantry, allowing for easy replacement of the corkscrew. This sleeve consists of a piece of pipe, acting as a sleeve, welded to square tubing.

The pouring and gripping function has several unique components. A Dynamixel MX-64T smart servo is responsible for the pouring motion. This motor has similar features to the AX-12A servos in the tower base and foil cutter, but provides the torque required for lifting a full bottle of wine. Section 0 covers the analysis that led to the selection of this motor. The bottle holder arm comprises an aluminum plate backbone, the neck clamp and its brackets, and the pivot standoffs. The backbone is made from waterjet-cut aluminum. The neck clamp was purchased. The pivot standoffs and neck clamp bracket were machined from aluminum rod and angle stock. The gripper curve was manufactured from a block of aluminum that we outsourced for CNC machining. Finally, the gripper sleeve is made from clear polycarbonate 4" diameter pipe, chosen for visibility of the bottle label.

The weight sensing task uses a micro load cell and its fixturing. This component was changed from a pressure sensor for easier mounting and integration since the load cell comes with tapped holes for mounting. A plate is attached to one end of the load cell for holding the wine glass. Standoffs connect the plate to the load cell and the load cell to the base plate, creating the height necessary for the weight sensing plate to match the level of the electronics box's upper surface.

The electronics box is made from aluminum sheet stock and was manufactured by Protocase. This box, as well as the external-facing aluminum components, were all powder coated to protect the aluminum and enhance the aesthetics of the device. Powder coating results in a better-looking finish around welds and sharp corners than anodization, the other finishing process that we considered.

Main power is conducted through 16-gauge wire. Although the device has not used more than 5 amps of current, we designed the system for a maximum power draw of 10 amps. Some of the peripherals use 18- and 20-gauge wire where appropriate, since no individual component draws more than 3 amps.

The user interface front panel features SPDT toggle switches and SPDT momentary buttons. Although the switches have two states, or throws, our design only makes use of the closed state, and is disconnected in the default state. The toggles control options that are meant to be either on or off, and the buttons are used as pour option selection and emergency stopping. Both types of switches were chosen for incorporating red LEDs. The toggle switches use synchronous LEDs, so that they turn on when the switch is in the "on" position. This set up makes it more intuitive for the user to know when a particular feature has been selected. The buttons have RGB LEDs and are manually switched through a relay board. This manual switching gives us greater control over the LEDs, allowing us to use the buttons as a status display. The relays are necessary because the LEDs run on the main 12V supply, while the microcontroller outputs 5V logic and cannot supply much current.

5.4 COST ANALYSIS

At the time of CDR, the budget estimate indicated the spending would not exceed the initially allotted funds of $4,500. $1,933.22 had been spent at that point, and the final design cost was estimated at $3,026 including shipping costs. The final Novel Wine Opener prototype exceeded the initial project budget because of underestimated part costs, replacement for components that broke unexpectedly, and rushed shipping costs. The final cost of the design process was $4,960. However, the total cost associated with the final build of the Novel Wine Opener is $3,050.

Prototyping costs totaled approximately $1900. These costs include prototyping materials such as wood and acrylic, prototypes of preliminary design iterations, foil cutters, glue, and fastening hardware. In the CDR report, shipping costs for this project were estimated at $400, which is approximately the total amount that was spent.

The manufacturing of the electronics box, which was outsourced to Protocase, cost much more than originally anticipated. Initially, the box was estimated to cost around $300. The functional and aesthetic design of the electronics box required sheet metal bending, seam welding, powder coating, and silk screening. Protocase was able to perform all of these processes, however the total cost of the box ended up being close to $600—13% of our initial budget for a single part. The gripper neck clamp was also more expensive than expected. A Stafford shaft collar was selected for this neck clamp and the expected cost was between $10 and $30—typical prices for a heavy-duty collar bracket. However, the shaft collar cost $117 because the collar consists of two separate halves attached by a hinge on one side whereas most shaft collars tighten and loosen, but do not open at a hinge – a feature necessary for the design of the gripper.

Three weeks prior to Cal Poly's Engineering Senior Project Expo, an unexpected electrical short occurred breaking multiple electronic components necessary for operating the foil cutter, cork remover, and rotating tower. Because the deadline for the project was quickly approaching, the broken components needed to be replaced as soon as possible. Replacement parts were purchased with rushed shipping, adding an extra expense, in addition to the parts themselves that would not have otherwise been required. This rushed order expended most of our remaining funds. A $500 increase in funds was requested from Mr. Swanson and approved, allowing us to finish the project with the necessary parts.

The most expensive Novel Wine Opener components are the electronics box ($583 - includes sheet metal bending, seam welding, powder coating, and silkscreen processes), pouring motor ($360), housing components ($283 - includes welding and powder coating costs), gripper curve ($148 - includes CNC cost), linear actuator for rotating tower ($139), and gripper neck clamp ($117). Precise position and velocity control necessitates the use of the expensive and compact motors mentioned. Additionally, the housing was designed as a structural component, requiring thick aluminum plates. These thick plates give the housing a sturdy feel and a consistent appearance, but considerably increased our material costs. The housing components did not require a powder coat finish to be functional, but the powder coat was added to make the Novel Wine Opener more aesthetically pleasing, as this was a strong desire of Mr. Swanson's at the start of the project. The cost of the finishing was well worth the aesthetic result, which matches the color scheme of the Center of Effort tasting room.

Some costs were conserved by taking advantage of manufacturing resources available on Cal Poly's campus rather than outsourcing all parts to vendors. For example, there was an option between sending a handful of parts to a CNC shop in town or machining them by hand in Cal Poly's Mustang 60 and Aero Hangar Machine Shops. The latter option was chosen, saving us a total of $460. Additionally, most of the Novel Wine Opener's aluminum parts were manufactured with the water jet in Cal Poly's Industrial Technology (IT) Machine Shop as opposed to outsourcing to a machine shop in San Luis Obispo, which saved approximately $300.

A full cost breakdown by part can be found in the Bill of Materials in Appendix I, and all budget and purchasing details for stock parts and vendors can be found in Appendix M.

5.5 SAFETY, MAINTENANCE, AND REPAIR CONSIDERATIONS

5.5.1 Safety

Several steps were taken to minimize the safety risks inherent to the wine opening device. The foil cutting blades and the corkscrew are the main sharp objects that have the potential to injure someone. However, each of these products are internally located, meaning other components are blocking most access to these objects. When these components are not in use, they are retracted to their most inaccessible position. Although this does not completely eliminate the potential for injury, this product does not have any fast moving or spinning parts that could seriously cause harm. Additionally, the product will only be used by employees of Center of Effort who will be trained on the use of the machine prior to working it.

Other potential concerns include the pinch points around the main linear actuator tower and the pouring tower. A clear acrylic safety shield was designed to eliminate the possibility of someone placing their fingers between the gripper backbone and the pouring housing on the downswing of the bottle. Additional reasons for incorporating this safety mechanism were discussed in section 5.2.

The operator's manual provided in Appendix N incorporates warnings about these pinch points but there are not any automated safety mechanisms. A complete list of potential hazards that were designed for can be found in Appendix J.

5.5.2 Maintenance

Significant maintenance is not expected for the Novel Wine Opener. However, there are two areas of concern: the foil cutting blades and the rubber caps attached to the tightening screws to hold the bottle in place. Firstly, the specific blades used in the product are serrated blades taken off of a Dual Blade Wine Foil Cutter by HQY. The foil cutter is designed so that the blades will be replaceable, but the frequency at which this will be necessary is unknown. Secondly, the rubber on the tightening screws has the potential to wear out over time. Wear out is not expected to happen frequently, but the specifics of replacing these parts will be included in the Operator's Manual (Appendix N).

An additional component that will likely need occasional replacing is the Houdini electric corkscrew, as it may dull over time. This component has been modified from its original state. Two modified corkscrews will be included in the replacement materials that will be delivered to our sponsor along with the Novel Wine Opener. Further details on how this corkscrew was modified are provided in Section 6.4. A guide for modifying the corkscrew as well as replacing it is included in the Operator's Manual.

5.5.3 Repair

The majority of this product was overdesigned in a way that ensures the unlikelihood of parts breaking. However, the wiring cables may get worn from friction or could potentially be damaged if spilled wine seeps into the electronics box. If the product is dropped, components such as the housing or the motors could potentially get damaged and need to be replaced. The housing is a custom part, so it will likely need to be outsourced in order to replace it, but all of the motors can be bought online and switched out. A complete troubleshooting and repair guide has been included in the Operator's Manual, and videos for more complicated operations are included with the all of the files relevant to the project.

6 MANUFACTURING PLAN

6.1 GRIPPER

The gripper, shown in Figure 6.1, consists of a transparent acrylic sleeve that supports the base of the bottle, a clasping mechanism that secures the neck of the bottle, and a support mechanism that attaches the gripper to the pouring tower.

FIGURE 6.1. GRIPPER ASSEMBLY

A 4" acrylic rod section, a 12" x 12" acrylic sheet, and adhesive glue must be procured in order to manufacture the base sleeve of the gripper. The acrylic sleeve was cut to the proper length using a A 4" acrylic rod section, a 12" x 12" acrylic sheet, and adhesive glue were procured in order to manufacture the base sleeve of the gripper. The acrylic sleeve was cut to the proper length using a horizontal saw, and two holes were drilled on opposite sides of each other. The acrylic sheet was laser cut to obtain a circular gripper sleeve base with drainage cutouts. The convex rubber insert was procured from Shapeways in order to create a raised center for the wine bottle punt to rest around. The rubber bottom provides more friction to resist the rotational slipping of the bottle during the operation of the machine. The sleeve base, sleeve tube, and convex insert are attached using adhesive glue.

A steel collar hinge [B110] is used to clasp the neck of the wine bottle. Holes were drilled into this collar hinge to enable attachment to the pouring mechanism via the custom L-bracket [B101].

The gripper attaches to the pouring tower with a backbone support structure. The support [B104] was made of 1¼" x 1¼" x 12" aluminum bar. The backbone support was modified to include drilled holes. A U-shaped clamp [B107] connects to the backbone and the gripper sleeve. A ¾" x 2½" x 6" aluminum bar was procured and machined into a U-shape, and two holes were drilled through both arms of the U. Custom screw rotational inserts [B106] were placed in these holes and attach the clamp to the gripper sleeve. The screw rotational inserts were machined from ½" x 12" steel rod. These inserts have two different outer diameters, a hollow center, and interior threading that matches that of two knurled head thumb screws [B108]. These thumb screws were screwed inside of the custom screw rotational inserts. Once the thumb screws were inserted through the acrylic sleeve and the ends of the U, the rubber end caps were attached to the ends of each using superglue. Inside of the neck clasp, two 3D printed rubber inserts [B114] were inserted. These rubber inserts squeeze the neck of the bottle and resist slipping vertically and rotationally. These inserts were procured and glued to the interior surfaces of the neck clasp.

6.2 LINEAR ACTUATOR TOWER

The linear actuator tower consists of a manufactured mounting plate [B201], turntable bearing [B202], turntable motor [B203], linear actuator [B206], and floating gantry [207]. The mounting plate, turntable bearing, and turntable motor bolt together to create a rotating base (Figure 6.2). The linear actuator connects to this base with additional V-slot [B102], procured corner connectors [B103], and water jet cut 2-hole brackets [B205] and extends through a hole in the electrical box as seen in Figure 6.3.

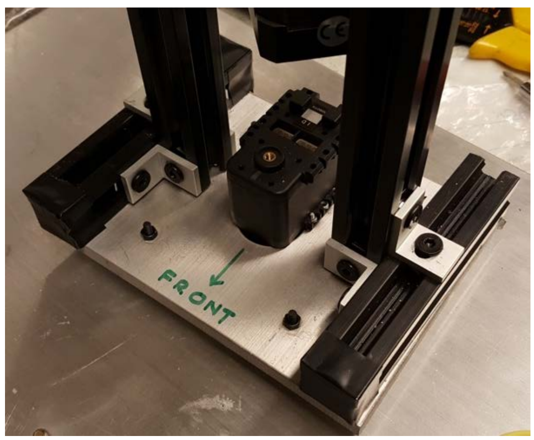


FIGURE 6.2 ROTATING BASE FOR LINEAR ACTUATOR

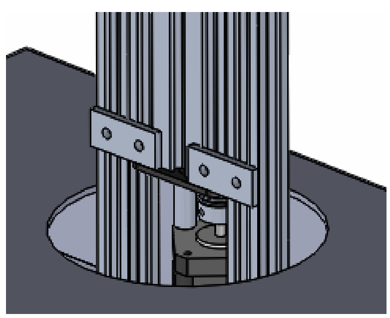


FIGURE 6.3 LINEAR ACTUATOR EXTRUDED FROM ELECTRICAL BOX

The main changes to this design since CDR are the changes to the floating gantry design. The initial plates [B301] did not fit well onto the linear actuator. We replaced these parts with replacement plates purchased from Openbuilds. This replacement served a dual purpose of minimizing manufactured parts and improving the fit on our floating gantry. The only parts in the linear actuator assembly that were manufactured are the waterjet upper mounting plate [B201] and the V-slot [B102] which was cut to length. The linear actuator lead screw had to be cut down as it was too tall for our needs. After these parts were machined, the whole assembly was put together with angle brackets [103], L-brackets [204], and fasteners.

The linear actuator's floating gantry [B207] is the location where the foil cutting and cork removing tool arms attach. The tool attachment arms are made of procured V-slot [B102] and square tube [B412, B501] for the foil cutter and corkscrew, respectively. These arms connect to the linear actuator gantries with L-brackets [B204], M5 flat nuts and M5 bolts.

6.3 FOIL CUTTER

The foil cutter is the device that has gone through the most design iterations since CDR. The new foil cutter, shown in Figure 6.4, consists of a rotational servo motor [B203], two linear servos [B402], two serrated blades [B405], a rotating top plate [B413], a rotating bottom plate [B401], and two blade holders [B403] all manufactured or procured, and mounted to the foil cutter tool arm.

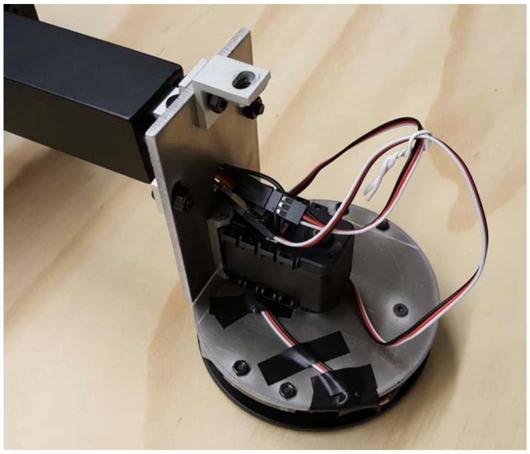


FIGURE 6.4. FOIL CUTTER WITHOUT HOUSING

The motor mounts to the tool arm using the motor mount plate [B414]. The motor shaft attaches to the rotating plate with procured fasteners. The rotating plates were made from 1/8" thick aluminum and were water jet cut. Two linear servos are sandwiched between the plates using fasteners. Both servos are attached to their own foil cutter bracket [B403]. Each servo is inserted into a hole in the foil cutter arm and is secured with an M3 bolt. The foil cutter blade holders [B403] were purchased from Shapeways and made from SLA Nylon. A serrated blade [B405] is attached to each holder using screws that are included with the purchased blade.

6.4 CORK REMOVAL

The cork remover consists of a modified Houdini electric corkscrew [B505], shown in Figure 6.5. The procured electric corkscrew normally operates with four AA batteries. The corkscrew rotates inside the black and silver housing when the silver button on the front panel is pressed.

FIGURE 6.5. HOUDINI ELECTRIC CORKSCREW

The electric corkscrew was modified to be powered and controlled along with the rest of the Novel Wine Opener functions. The silver housing was removed, and the black housing was unscrewed and split in half in order to access the product's internal electric components. An exploded view of the corkscrew's internal components is shown in Figure 6.6.

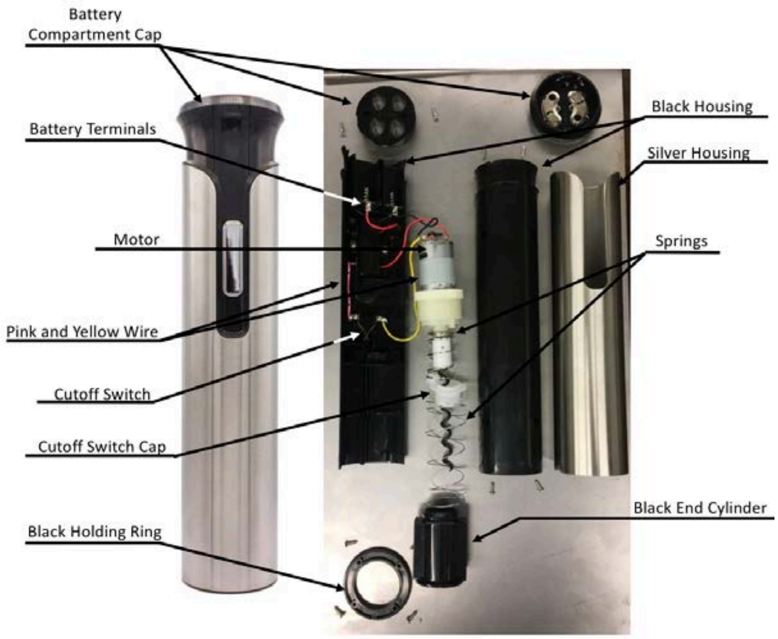


FIGURE 6.6 ELECTRIC CORKSCREW INTERNAL COMPONENTS

The pink wire connected to the switch and the red wire connected to the motor were cut where the two wires connect to the button. The second red wire, which was connected to the battery terminal, and the two black wires were completely removed. All of these wires are shown connected in Figure 6.7 and disconnected in Figure 6.8.

FIGURE 6.7 CORKSCREW PINK, RED, AND BLACK WIRES

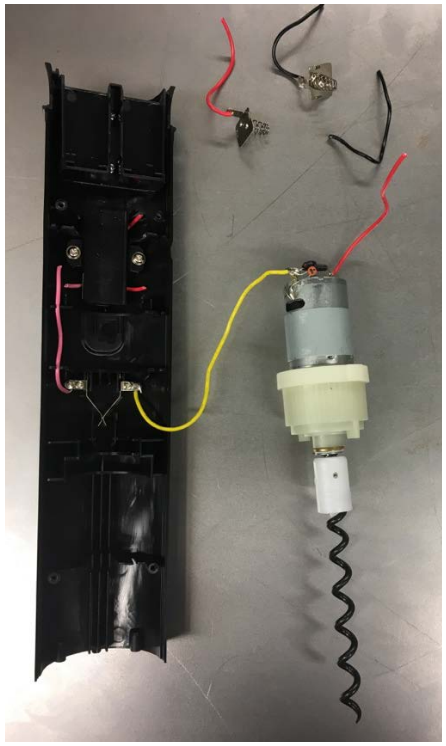


FIGURE 6.8 CORKSCREW CUT AND REMOVED WIRES

A hole was drilled into the black housing in the location shown in Figure 6.9. This hole allows wires to be routed out of the cork remover and into connection with a motor driver.

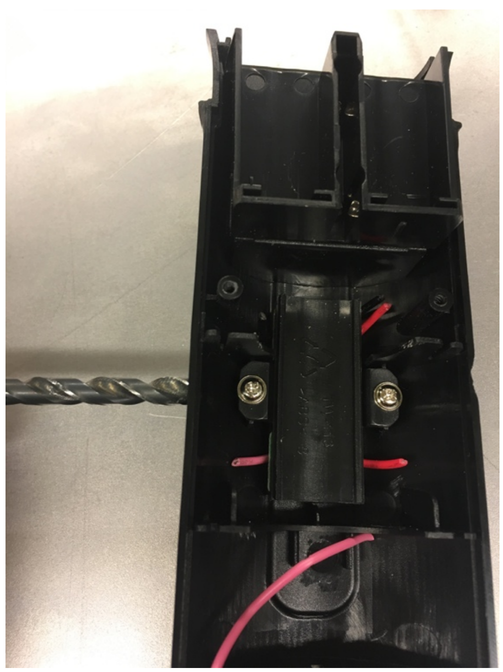


FIGURE 6.9 DRILLED HOLE IN BLACK CORKSCREW HOUSING

After the whole was drilled, the cut ends of the pink and red wires were stripped and soldered to new wires. The soldered connections were covered in heat shrink, and the ends of the new wires were stripped and covered with quick disconnect terminals. A diode was soldered to the pink and yellow wires connected to the switch. The white band of the diode faces the yellow wire. The switch connections are shown in Figure 6.8. After the wires were re-soldered and the diode was added, the new wires were routed through the drilled hole, and the motor and springs were repositioned inside of the black housing, as shown in Figure 6.10.

FIGURE 6.10 CORKSCREW HEAT SHRINK AND QUICK DISCONNECT TERMINALS

The wires connect to a motor driver chip [B618] (housed in the electronics box), which allows the rotation of the corkscrew to be controlled with code and an Arduino microcontroller, rather than by physically pressing a button. The two black housing pieces were screwed back together. The modified electric corkscrew is shown in Figure 6.11.

FIGURE 6.11 MODIFIED ELECTRIC CORKSCREW

See Section 6.8.3 for the manufacturing of the cork remover housing.

6.5 POURING

The pouring tower, shown in Figure 6.12, consists of a MX-64T motor [B105], tower structure, and a gripper with structural backbone as described in Section 6.1. The backbone is made of two pieces, a vertical member [B104] and a U-curve [B107]. The tower structure is made of procured linear rail base V-Slot [B103]. The only design change from CDR for this structure is that the mounting plate for the motor is now integrated into the housing. The gripper backbone is bolted to the motor horn of the pouring motor through two spacers [B115]. These spacers were added after CDR to space the gripper far enough away from the pouring housing to prevent scraping. The whole tower is mounted to the base of the electrical box using 4 aluminum angle brackets [B103].

A small stopper peg was initially going to be included to stop the bottle from hitting the wine glass and knocking it over. After testing the pouring motor and the mechanism, the peg was determined unnecessary. However, the space between the pouring tower and gripper was determined to be a pinching hazard for public use. Because of this, a removable hand guard [B116] was added to prevent users from sticking their fingers into a pinch point area during pouring.

FIGURE 6.12 POURING TOWER WITHOUT HOUSING

6.6 SENSING WEIGHT

The weight sensing mechanism, shown in Figure 6.13, consists of a 0.78 kg micro load cell [B801] and a circular plate [B802] for a wine glass to rest on.

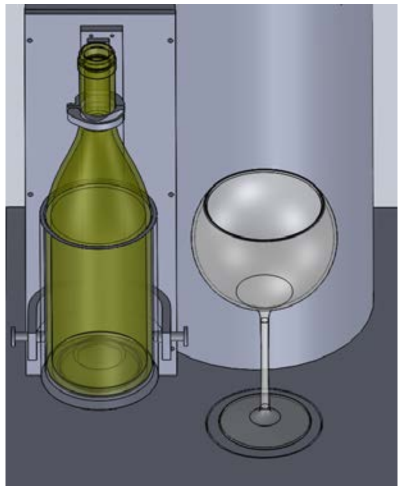


FIGURE 6.13. SENSING WEIGHT

The circular plate was waterjet cut out of 6” x 6” x 1/8” aluminum. The load cell connects to the circular plate via 6 aluminum standoffs [B803, B804] (Figure 6.14), placing the aluminum plate level with the electronics box.

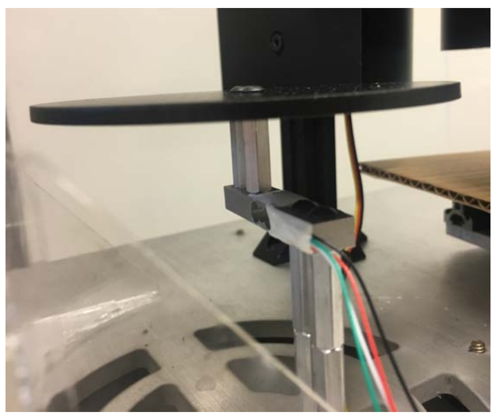


FIGURE 6.14 WINE GLASS PLATE ON STANDOFFS

6.7 USER INTERFACE

The user interface consists of toggle switches [B701], LED buttons [B702], a LED relay board [B703], and wires [B704] mounted onto the front panel of the electrical box shown in Figure 6.15. These user interface components connect to an Arduino inside of the electrical box with wires. The wiring diagram and pinout table for all user interface connections are provided in Appendix O.

FIGURE 6.15. USER INTERFACE

6.8 HOUSING

The wine opener housing consists of three cylindrical covers for the rotating tower, foil remover, and cork remover. A semi-circular cylinder houses the pouring tower, and an electrical box covers all of the electrical equipment. The following sections provide manufacturing details for each housing. Each housing component was powder coated flat black after manufacturing was completed.

6.8.1 ROTATING TOWER HOUSING

The rotating tower housing, shown in Figure 6.16, was made out of a 7" diameter aluminum tube and a sheet of 1/4" aluminum [B210]. The tube was cut to a length of about 22.5" using a mill. Two 12.25" by 1.4" slots were cut 180 degrees apart from the top of the cylinder. The slots were cut with a mill and allow the foil cutter and cork remover arms to extend out of the housing.

FIGURE 6.16 ROTATING TOWER HOUSING

A 7" diameter circle was cut out of the aluminum sheet with a water jet for the rotating tower housing cap [B208]. A ring [B209] with 6.875" diameter and 0.375" thickness was also cut from the sheet using a water jet. The cap and the ring each have two tabs extruded from the circle, located 180 degrees from each other, which mate with the slots in the cylinder as shown in Figure 6.17. The full circular piece was connected to the two hollow pieces using L brackets [B204] to form a full cap for the cylinder. The full circle rests on top of the cylinder, and the entire cap fastens onto the cylinder with L brackets.

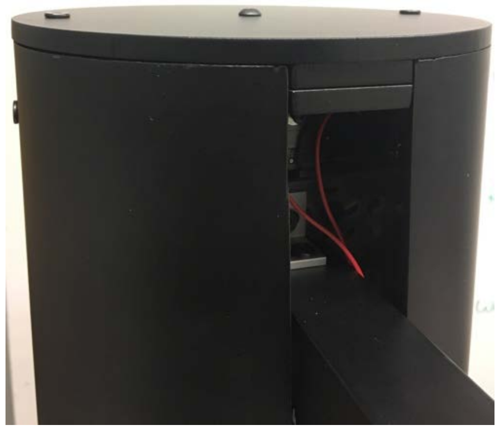


FIGURE 6.17 ROTATING TOWER HOUSING CAP AND CYLINDER MATE

6.8.2 FOIL CUTTER HOUSING

The foil cutter housing, shown in Figure 6.18, was made out of a 5" diameter aluminum tube [B409] and 0.25" aluminum sheet. A 5" diameter circular plate [B410] was cut out of the aluminum sheet with a water jet. The tube was cut to about 5.25" in length and a 3.85" by 0.825" slot was cut starting at the bottom of the tube with a mill. The circular plate was welded onto the top of the tube, and the welds were sanded down to be flat. The foil cutter housing connects to the foil cutter with L brackets [B204]. The arm that connects the foil cutter to the rotating tower is housed with a square aluminum tube [B412] cut to about 3.25" in length. This arm mates to the cylinder of the housing with L brackets. A thin sheet of aluminum [B411] fastens below the arm to cover the rest of the slot and the internal foil cutter components from view.

FIGURE 6.18 FOIL CUTTER HOUSING

6.8.3 Cork Remover Housing

The cork remover housing was made out of 1/4" aluminum sheet, a 2.5" outer diameter circular aluminum tube [B502] with a 0.065" thickness, and a 1" by 1" square aluminum tube [B501] with a 0.125" thickness. Two 2.5" diameter circles [B503, B503] were cut out of the aluminum sheet using a water jet cutter. One of the circles had an additional circle cut out of the center of it, leaving a 0.13" thickness around the edges. Two holes were drilled into the solid circle and counter-bored to accommodate 0.08" diameter screws. Four holes were drilled and counter-bored into the second water jet piece to accommodate 0.10" diameter screws. The counter-bored piece is shown in Figure 6.19.

Figure 6.19 Corkscrew Counter-Bored Holes

The counter-bored holes line up with the threaded holes in the electric corkscrew used to secure the silver housing onto the black housing. A couple of these holes are shown in Figure 6.20.

Figure 6.20 Corkscrew Holes for Housing Connection

The circular tube and the rectangular tube were shortened with a mill until they were about 10" and 5.75" long, respectively. A semi-circle, or fish mouth, was cut into one end of the rectangular tube so it would mate with the circular tube using a tube notcher. The two tubes were welded together at this mating point. The 0.13" thick circular aluminum plate was welded onto the bottom of the circular tube as shown in Figure 6.19. The welds were sanded down, and the corkscrew was secured into the housing with screws. The 2.5" diameter circular aluminum plate was secured on top of the circular tube with screws, totally enclosing the corkscrew. The cork remover housing is shown in Figure 6.21.

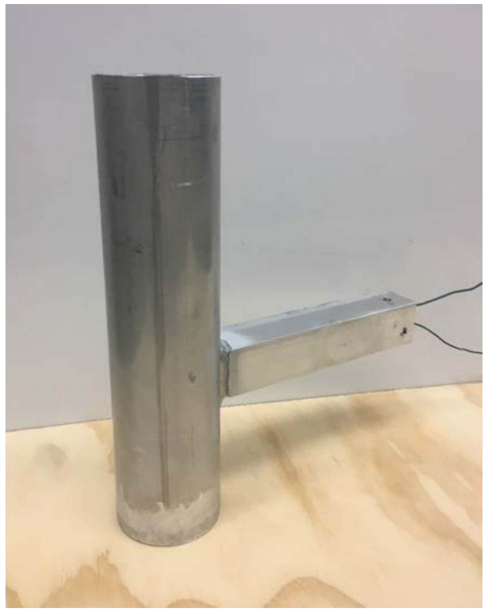


FIGURE 6.21 CORKSCREW HOUSING, UNFINISHED

6.8.4 POURING TOWER HOUSING

The pouring tower housing, shown in Figure 6.22, consists of a semi-circular cylinder [B118] with a semi-circular cap [B119] and a rectangular plate cover [B120]. The semi-circular cylinder was manufactured from a 4.5" diameter tube. The tube was cut to about 12" in length and was cut in half lengthwise with a mill. The semi-circular cap was made from 1/4" aluminum sheet. A semi-circle with 2.25" radius was cut out of the sheet with a water jet cutter. This cap was welded to the top of the semi-circular cylinder. The rectangular plate cover was also cut out of 1/4" aluminum sheet with a water jet cutter. This plate is 12" by 4.5" and was welded onto the front of the semi-circular cylinder after four holes were counter-bored into it, equally spaced along the centerline of the plate. The welds from the cap and the plate were sanded down. The welded housing structure connects to the V-slot making up the pouring tower as well as the gripper backbone (also shown in Figure 6.22) with L brackets and other fasteners.

FIGURE 6.22 POURING TOWER HOUSING

6.8.5 ELECTRICAL BOX

The electrical box, shown in Figure 6.23, was manufactured by Protocase. The box was made out of a piece of sheet metal with holes cut in it to fit over the rotating tower and pouring tower, as well as holes for the toggle switches and LED buttons that make up the user interface. This piece of sheet metal was bent into a box with an 18” by 12” footprint. The edges of the box were seam welded. After bending and welding, the box was powder coated gray, and white letters were painted onto the user interface panel by a silk screening process.

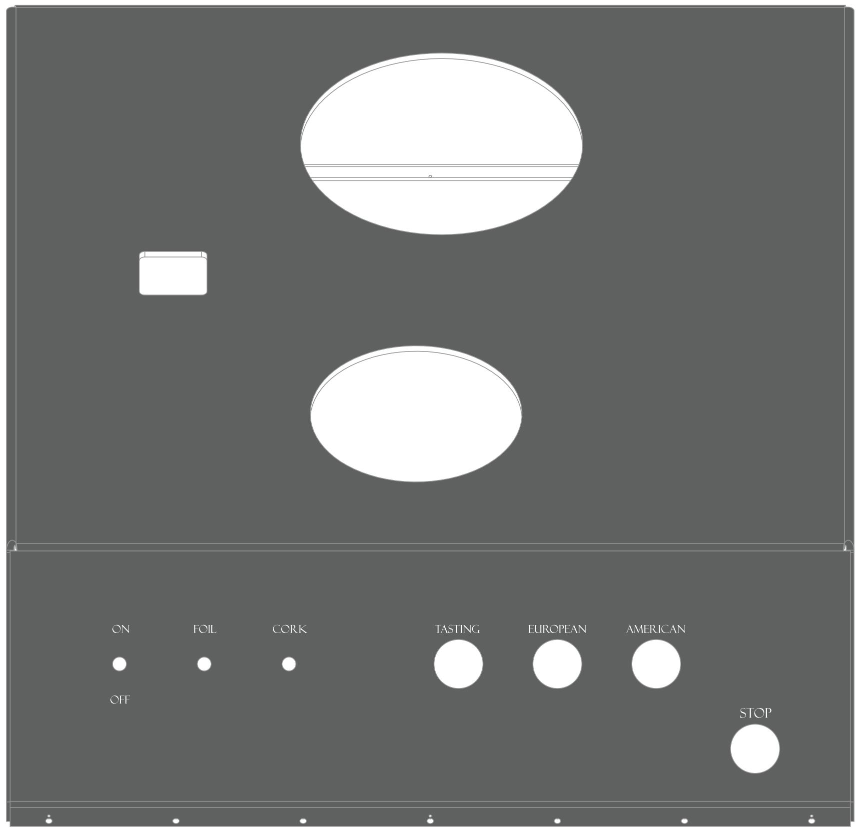


FIGURE 6.23 ELECTRICAL BOX

6.9 ELECTRICAL SYSTEMS

Several subsystems of wires route power and control signals to the various components of the device. Although the device takes 12V power in from a barrel jack at the rear of the electrical box, two 5V systems and a 6V system are also present. Simple on/off 5V logic drives a number of the systems, but the motors run on serial TTL or servo PWM signals.

The initial designs accounted for a single Arduino Mega microcontroller and associated accessory shields/motor drivers. As the design progressed, additional chips, boards, and electronics were added to support all of the components. The most recent revision of the **control system** comprises:

- the Arduino stack (including AX-12A servo shield and load cell shield) (part B608),
- a custom auxiliary routing board (part B616),
- a DC motor driver board (part B618),
- a DC relay board for the LEDs (part B703), and
- a 5V regulator circuit to drive the relays (part B705).

Inputs include:

- the weight-sensing load cell (part B801),

- a limit switch on the linear actuator tower (part B211), and
- the toggles (part B701) and buttons (part B702) on the user interface panel.

The **outputs** of the system are:

- the LEDs (in the buttons and toggles) in the front panel switches,
- two AX-12A servomotors (control the rotation of the main tower and the rotation of the foil cutter) (part B203),
- one MX-64T servomotor (controls the pouring) (part B105),
- two linear servos (control the horizontal movement of the foil cutter arms that engage the serrated blades into the foil) (part B402),
- a stepper motor (controls the vertical motion of the linear actuator of the main tower) (part of part B206), and
- a simple DC motor (controls the corkscrew(part B505).

The biggest wiring challenge was designing wires to work with the rotational components. As the tower rotates and moves vertically, it carries the corkscrew, one AX-12A servo, the linear servos, and the tower limit switch. Furthermore, the linear servos rotate with the foil cutter. In order to avoid the likely possibility of the foil cutter wires snagging and breaking as both the foil cutter and the main tower rotate, these motors were daisy-chained. The foil cutter rotational servo is plugged into the servo at the base of the tower, meaning that the wire to the foil cutter rotational servo never deals with rotation. The rest of the wires were cut with enough slack to accommodate the tower rotation and lifting. The servo-type wiring was implemented with break-away connectors near the base of the tower, allowing the wires to disconnect cleanly in the event of a snag rather than breaking.

6.9.1 Control Boards

An Arduino Mega microcontroller forms the basis of the wine opener's control system. Stacked directly onto this board are a Dynamixel smart servo controller and a Wheatstone bridge reader shield for the load cell (Figure 6.24). These shields permit the Arduino to talk to the AX-12A motors and load cell. It is directly connected to the relays for the LEDs, the buttons and switches, the DC motor driver chip, and an auxiliary routing board.

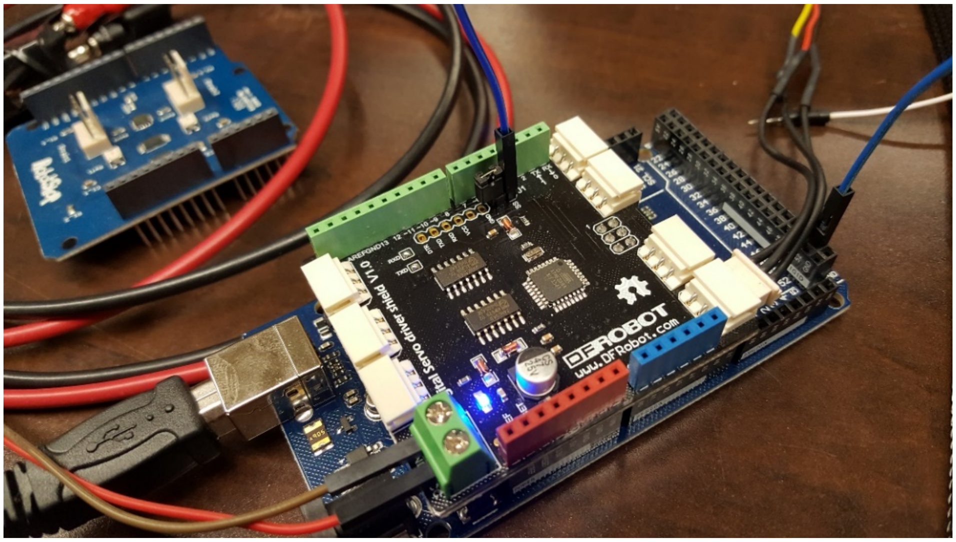


FIGURE 6.24. DYNAMIXEL SERVO SHIELD AND LOAD CELL SHIELD.

To condense some of the wiring and control signals, a custom circuit board was developed, seen in Figure 6.25. This board houses the 74LS241N tri-state buffer (shown near the bottom of the figure) and MX-64T connector, A4988 stepper motor driver, linear servo connectors, and 6V distribution.

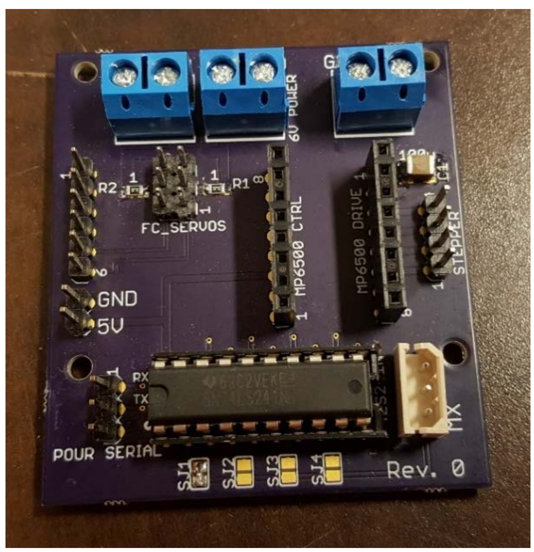


FIGURE 6.25. CUSTOM AUXILIARY BOARD.

The DC motor driver chip and stepper motor chips are interfaced through Pololu-brand carrier boards. The VNH5019 DC motor driver is mounted on its own because of its larger footprint. The A4988 is small enough to easily mount onto the auxiliary board (Figure 6.26), and is convenient to do so because of the many control pins. The design uses only a handful in order to simply run the stepper in the forward and reverse directions.

All of the control boards are attached to the base plate via nonconductive nylon M3 standoffs except the VNH5019 board, which uses 2-56 standoffs. Using nonconductive/nonmetallic standoffs is especially important for the Arduino, which has a number of exposed power pins on the bottom close to the mounting holes.

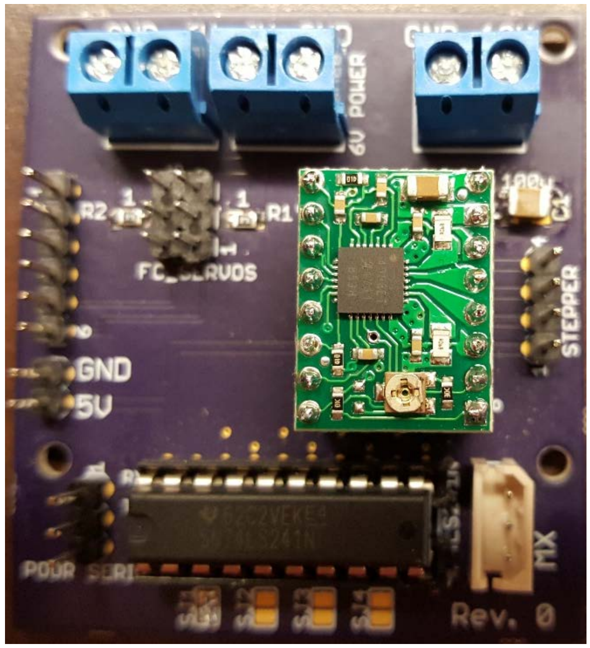


FIGURE 6.26. A4988 STEPPER MOTOR DRIVER (GREEN PCB), INSTALLED INTO AUXILIARY BOARD.

6.9.2 MOTORS

The Dynamixel motors use 2.50mm, 3-pin Molex SPOX connectors rather than typical 0.1" Dupont pin connectors. Since long cables in 1100 mm length for these motors could only be purchased and were on backorder everywhere, replacement connectors and wire were purchased instead and used to build cables for the three Dynamixel motors. The long servo cables to the foil cutter linear servos were also made to length.

The two AX-12A motors connect to the servo shield on the Arduino, while the stepper, pouring motor, and foil cutter linear servos connect to the auxiliary board (Figure 6.27 and Figure 6.28). When attaching the stepper, the red wire goes to pin 1 on the header. The MX-64T pouring motor can only be plugged in one direction. The linear servos use the pair of servo headers near the middle of the board, black wires on the side with the screw terminals.

If the motors are not connected in the correct orientations, they may either run backwards or not at all. When troubleshooting a motor, if something was unplugged recently, the header connections should be checked first.

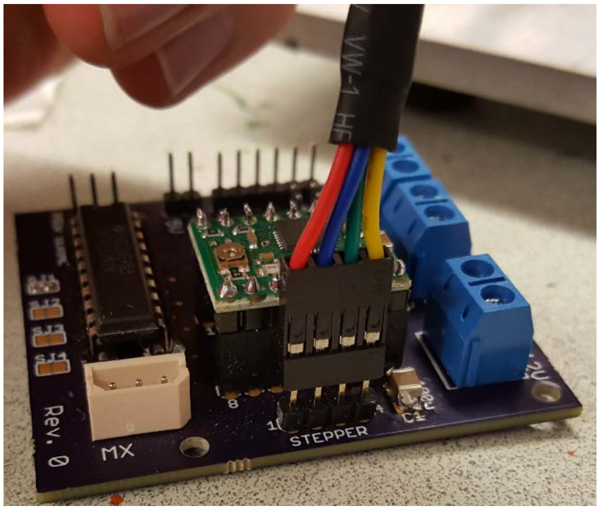


FIGURE 6.27. MX-64T (WHITE CONNECTOR AT LEFT) AND STEPPER MOTOR CONNECTIONS.

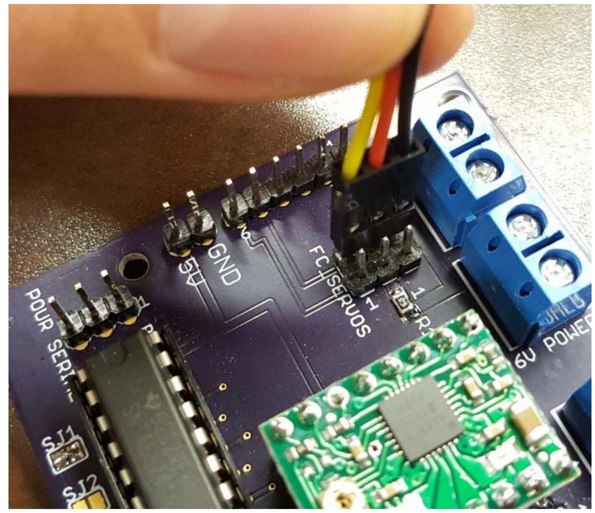


FIGURE 6.28. HEADER FOR LINEAR SERVO CONNECTORS.

6.9.3 SENSORS

Feedback into the controller is provided by the load cell and tower limit switch. The load cell, suspended between the base plate and wine glass plate on standoffs, closes the loop in the pouring controller. The load cell is pre-threaded for M3 screws, making it easy to directly attach. It connects to one of the two headers on the load cell shield (Figure 6.29), which is configurable in the program. When connecting the load cell, orient the connector with the black wire towards the middle of the shield. Otherwise, the load cell will not provide correct readings.

At the top of the tower is a limit switch that defines the uppermost position of the linear actuator tower. Since the tower is driven by a stepper motor, which has positional accuracy only as long as the motor does not slip, start new pouring operations at the top of the tower and use that as a reference. The limit switch, like all of the other buttons, is defined as a pull-up input which becomes active when shorted to ground.

The pouring controller and linear actuator tower are the only systems with external sensors All other systems are run in open loop, although the other motors have internal feedback for positional control.

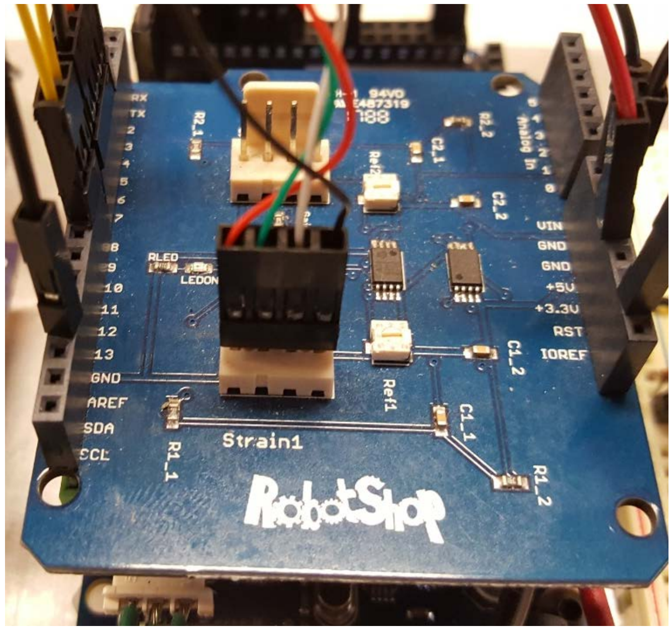


FIGURE 6.29. LOAD CELL CONNECTION TO SHIELD. NOTE THAT THE **BLACK** PIN IS CLOSEST TO THE CENTER.

6.9.4 LEDS

The LEDs in the toggle switches and buttons are driven on 12V power. Each LED pin has a 330Ω resistor connected in series to limit the current draw. A mechanical relay board is used to control the button LEDs from the Arduino. Because the Arduino is limited in how much current it can supply through its 5V pins, and having more than 2 relays on at a time exceeds this limit, we added an external supply for the relay board. A LM7805 voltage regulator (part B705) with decoupling capacitors (reference the chip's datasheet, included in the attached drawings and spec sheet packet) is used to step the main 12V power down to 5V for the relay board.

7 DESIGN VERIFICATION PLAN

Following is a description of the ways in which the structural and final prototypes of the wine opening machine haven been tested to verify first that each individual function works and subsequently the functionality of the product as a whole. The structural prototype was tested first but the following results are based on the tests from the final assembly. The wine opening machine was able to perform the majority of the tests, but did fail in a few ways – some that were expected, and some that were unexpected.

All of the following test descriptions could have been performed in any location, as the product is not affected by its environment, although every test was conducted in the Cork and Gear senior project room in the Bonderson building at Cal Poly. The Design Verification Plan, which gives a condensed version of the following results, can be found in Appendix K, along with the test procedures and results.

7.1 GRIPPING

The gripper had been one of the more concerning aspects of the design because it needs to hold colder wine bottles with condensation on the exterior. This factor has the potential to make the bottle slippery. To test this, we submerged multiple wine bottles in water before placing them into the gripper. Only the corkscrew and foil cutter were run as these are the functions that place the most torque on the bottle. By carefully observing the bottle during and after these operations, we were able to determine if the gripper successfully held the bottle.

As rotational and vertical slipping was Mr. Swanson's main concern with our first design, the final gripper design was developed to ensure the most support possible without a clunky appearance. This was the focus of the original redesign, so our team was confident that slipping would not occur - the success of this gripper was as expected, and Mr. Swanson's request to keep the wine label facing forward during operation has been fulfilled.

7.2 TOWER/LINEAR ACTUATOR

The linear actuator tower was built as part of the structural prototype and was integrated into the final prototype, meaning the functionality of it did not change. The rotational servo has consistently rotated to a give position from the start, although this was solidified on the final assembly. The stepper motor has more than enough power to lift the floating gantry and the weight of the tool arms attached. A limit switch was added to the top of the linear actuator to indicate that the floating gantry has been lifted the full amount. This helps the machine reset after each operation and prevents the possibility of the gantry not lifting the tool arms high enough over the bottle.

In addition to the weight of the gantries, the linear actuator needs to be strong enough to lift the foil cap off of the wine bottle while the linear servos are still squeezing the neck of the bottle. Through testing, it was found that this too, was not an issue for the stepper motor.

7.2.1 CENTERING

The AX-12A turntable motor was used to center the tool arms over the bottle in order for the operations to take place. As the full operation of the machine was being tested, we were able to verify the accuracy of the motor and its consistency in rotating to the desired angle. Originally on the final prototype, the setpoints needed to be adjusted slightly to get the tools directly centered. After testing multiple bottles and running the machine over a period of a week or two, it was apparent that the turntable bearings were gathering a lot of friction and causing the motor to overshoot or undershoot the setpoint. This was fixed by applying grease to the bearings, which prompted adding an instruction in the operator's manual to grease the bearings every month, and if the tool arms stop getting centered correctly. The grease has successfully fixed this issue, although we found that the stepper motor occasionally causes the corkscrew housing to land on the top of the bottle instead of dropping over it. As a result, the turntable motor was modified to "wiggle" its position after the stepper motor has dropped, to ensure that the corkscrew falls over the top of the bottle and is able to remove the cork.

After additional testing, the tools have been consistently centered and the operations have been able to successfully take place. Although the slight offsets were unexpected, they were a rather easy fix.

7.2.2 Driving the Corkscrew

Since the corkscrew mechanism is attached to a free-floating gantry, the weight of the gantry must be large enough to drive the corkscrew into the cork. This can be verified simply by placing a bottle with a cork under the corkscrew and commanding the corkscrew to spin into the cork. If the corkscrew simply spins atop the cork, the gantry is not heavy enough.

Initially, without the housing, we found that the floating gantry was not actually heavy enough and that we had to press down on the tool arm to allow the corkscrew to drive. After getting all of our finished housing parts and adding them to the gantry, the corkscrew was driven into the cork every time. Throughout testing there was never a problem with this.

One issue that we came across was that of adding a safety feature. The slots in the main housing give a good view to the linear actuator, wires, and other internal features in addition to creating a pinch point. To fix this, we purchased brushes to attach to the inside of the housing. Unfortunately, these brushes were far too stiff, and set us back to our initial problem of not enough weight to drive the corkscrew. With the lack of time left when we added this feature, we did not have a quick fix, and were forced to remove the brushes in order for the opener to work properly. Adding weight to the gantry would not be a particularly difficult task, but it would take a bit of time to figure out how, where, and what to attach that would not affect the overall functionality.

7.3 FOIL CUTTER

The foil cutter was one of the most difficult functions to implement, so the testing took place over an extended period and with multiple iterations of the design as was discussed in an earlier section.

7.3.1 Cutting the Foil

The foil cutter was initially tested by manually engaging the foil cutting subsystem that is attached to the tower onto the top of the bottle. In this way, we were able to narrow down the range of issues that could arise. The initial issue was the stability of the brackets in conjunction with the force placed on the foil. When this was fixed the second issue was the smoothness of track that the brackets followed. The foil was being cut more effectively, but not without a little manual help to the servos. Finally, the final design was implemented and tested, proving to be the most effective and efficient design based on the consistency of the foil being cut.

Once we determined that the foil was capable of being cut on a consistent basis, the controller for it had to be modified. Depending on the thickness of the foil, it was not a particularly clean cut and would frequently rip the foil. As a solution, the linear servos were programmed to step in a small bit further each time the rotational servo switched directions. This allows small creases in the foil to be formed before the pressure that previously caused the rips occurs, preventing the possibility of rips.

Testing and improving the foil cutter was a relatively linear process because we were often able to find a solution to fix each problem we came across before finding the next problem, and eventually coming to the perfect solution. At the final testing process, the foil cutter cuts the foil 100% each time, proving the design to be successful.

7.3.2 Removing the Foil

Testing the removal of the foil had to be performed after the foil cutting mechanism has been verified. Since we were able to get the foil cutting process down successfully, we simply had to verify that the linear servos could maintain their force on the bottle while the stepper motor lifted the gantry away from the bottle. Our first try for this proved to be successful, and the only issues we came across were those where the foil was ripped instead of cutting cleanly. This foil cutter problem was fixed quickly, and there have not been issues removing the foil cap from the bottle since.

7.4 CORK REMOVAL

The cork removal testing process took place concurrently with the weight testing of the free-floating gantry that it is attached to. The only reasons the cork would occasionally not be removed was because of other functions not working properly. For instance, if the corkscrew was not centered properly, the corkscrew would drive into the bottle at an angle, eventually hitting the inside of the neck of the bottle, unable to continue rotating, and stalling the corkscrew motor. Similarly, if the weight of the gantry not heavy enough, the corkscrew would not be able to drive into the cork at all, and the device was never able to attempt cork removal.

7.5 POURING

The pouring function was one of the most difficult to get right because of the +- 5% pouring accuracy that is required of the device. The easiest thing to look for is spilling which was checked each time the pouring was run. The second was pouring accuracy. The pouring accuracy needs be constant whether the bottle is full or almost empty, and it is expected that the programming will need to change between the two. The machine will first be tested for 5 ounce pours only to make sure that we can get this function to work at all. The pouring tests will be conducted on all of the Center of Effort bottles at least 5 times each. When the machine can consistently pour 5 ounces each time it runs from the time the bottle is full to the time it is empty, the pouring will be a successful function. If time permits, the programming will be adjusted, and this same process will be repeated for different size pours. The same acceptance criteria will be applied to each size pour.

8 PROJECT MANAGEMENT

This section includes information introduced in the Critical Design Review document. Changes to this section include an updated table of key deliverables to reflect the milestones completed over the course of the entire project.

8.1 COMPLETED PROCESS

The design process encompassed three main segments: design, build, and test. Each segment spanned a ten to twelve-week period during Cal Poly's fall, winter, and spring quarters. For a breakdown of the tasks and milestones completed, see Appendix L for the Gantt chart. Key deliverables and the dates they were completed are listed in Table 8.1. Scope of Work, Preliminary Design Review, Critical Design Review, and Final Design Review are tabulated in bold, as the presentations and reports generated for each were the largest milestones throughout the project process.

TABLE 8.1. KEY DELIVERABLES

DATE	DELIVERABLE
10/14/17	**Scope of Work**
11/2/17	Concept Selection
11/7/17	Concept Prototype
11/14/17	**Preliminary Design Review**
1/23/18	Structural Prototype
1/30/18	Detailed CAD / Manufacturing Plan
2/6/18	**Critical Design Review**
2/15/18	Safety Review
3/13/18	Manufacturing and Test Review
5/15/18	Hardware / Safety Demonstration
5/29/18	Operator's Manual
6/1/18	**Final Design Review Report**
6/1/18	**Senior Project Expo**
6/9/18	Final Prototype Delivered

The design accomplishes the following independent actions: remove foil, uncork the bottle, pour a glass of wine, and re-pour successive glasses of wine. Each of these actions make up a subsystem that, when combined, construct a fully functioning device to open and pour a bottle of wine. Before completing a comprehensive prototype, a preliminary prototype of each subsystem was completed. Once the mechanical, electrical, and software aspects of each function successfully operated, all functions were integrated mechanically and electrically onto one base plate. Software programs for each were run on one Arduino.

One of the engineering specifications was for the fully functioning device to operate on AC and DC power. Initially, a prototype was designed that could be plugged into AC power. The final prototype has a standard 5.5mm barrel jack that accepts 12V DC power, whether from an AC power converter, or a 12V battery.

8.2 DEVIATIONS FROM PLANNED PROCESSES

Most deviations from the planned project timeline occurred after Critical Design Review. The Gantt chart included in the Scope of Work, Preliminary Design Review, and Critical Design Review indicated that late March through the end of May would involve two weeks of testing the Novel Wine Opener design, two weeks of re-working the design as needed, three weeks of building the final prototype, and two weeks remaining weeks before Expo of writing the final report. In reality, the timeline from the middle of February to the beginning of June was split into large groups of tasks for manufacturing, testing, and Final Design Review. The full list of these tasks is shown in the Gantt chart included in Appendix L.

Individual functions were manufactured, tested, re-designed, and re-manufactured over the course of almost two months. After an individual function worked mechanically, its electronics and software programs were tested and adjusted for another one to two months, depending on the function. Manufacturing and preliminary testing of each function took place simultaneously from the middle of February to about the middle/end of May.

Once the electronics and software of each individual function worked satisfactorily, they had to be integrated onto one Arduino and one baseplate. More preliminary testing was necessary to ensure all functions performed successfully in the correct order on one Arduino. Integration began in early April and continued until late May.

Final testing was completed the last week of May because all of the preliminary testing had to be completed before the test plans could begin. The final assembly of all mechanical and electrical parts was not completed until May 31st. This tight timeline occurred because the final electrical box was not yet ready, so a temporary box was constructed out of wood for the project expo. The Operator's Manual, expo poster, and this report were worked on for the entire month of May and completed in the last week of May.

Overall, the timeline between February and June 1st was much more rushed than originally anticipated for a variety of reasons. The cycle of manufacturing, testing, re-designing, and re-testing as well as integration of all functions took much longer than anticipated. In addition, we ran into some issues beyond our control that set us back timewise, such as an electrical short that we encountered when mounting our electronics to the base plate for the first time.. Outsourcing parts to machine shops ultimately took more time than we comfortably had available. The gripper curve was manufactured by Cyclonetics Corporation in town, which took two and a half weeks. The electrical box was manufactured by Protocase, including powder coating and silk screen finishing. Due to production delays on their end, manufacturing was not completed until the last week of May. This experience taught us to allow ample buffer room (more than you think you need) in a project timeline to account for any unexpected design issues, malfunctions, or long supplier lead times.

9 CONCLUSION AND RECOMMENDATIONS

The purpose of this document is to define the scope of this project, outline the project timeline, describe idea generation processes, provide detailed explanation of the components of the design, lay out the manufacturing methods for each component, and provide testing results for the Novel Wine Opener.

At the conclusion of this senior project course, our team successfully delivered a working product that was able to open a bottle of wine and pour a glass. The final prototype met several of our design specifications, including sizing and timing requirements. It failed to meet some specifications and tests, specifically component wear, pouring accuracy and cleanliness, spill protection, and opening wax bottles. Overall, our team and our sponsor considered the project to be successful in terms of the design process undertaken, the lessons learned, and the functionality of the final prototype.

9.1 FUTURE DEVELOPMENT SUGGESTIONS

An Operator's Manual and replacement parts for components that may wear out will be provided to Center of Effort Winery. The Operator's Manual includes instructions for how to operate the Novel Wine Opener, how to replace parts, and how to troubleshoot any issues that may arise.

Further development of the pouring controller is the main suggestion for future development of the Novel Wine Opener. As the device currently operates, a small dribble of wine sometimes misses the wine glass during pouring, which is not ideal. However, automated pouring is a very complex problem to solve. Clean pouring is next to impossible to achieve without a 6 degree of freedom robot arm, which can move in multiple axes. This would likely involve the use of a larger motor, which would additionally require modified pouring tower housing. Cork and Gear feels that developing a pouring controller that accurately pours and senses the volume of wine in a glass could constitute an entire senior project.

10 WORKS CITED

Bishel, Richard. "WINE VERSER: A Robotic Pourer That Pours the Perfect Glass."*Kickstarter*, 23 Dec. 2014, www.kickstarter.com/projects/272225169/wine-verser-a-robotic-pourer-that-pours-the-perfec?ref=nav_search.

Brandi Makes Magic. "Disney's Very Own Wine-Pouring Robot....very Cool #Eatdrinkcreate #Lifeatdisney #DisneyRecruiter Pic.twitter.com/EFyCJBbhmY."*Twitter*, Twitter, 29 Sept. 2016, twitter.com/RecruiterBrandi/status/781315187655766016.

Chow, Yip C. *Combination Corkscrew and Stand*. 5 Sept. 1989.

Famili. "Famili FM700BR Rechargeable Cordless Electric Wine Bottle Opener with Foil Cutter, Opens up to 180 Bottles with One Charge, Black: Kitchen & Dining." *Famili FM700BR Rechargeable Cordless Electric Wine Bottle Opener with Foil Cutter, Opens up to 180 Bottles with One Charge, Black: Kitchen & Dining*, Amazon.com, www.amazon.com/dp/B06VVKWVTJ?psc=1.

Holloway, April. "More than Fifty Ancient Greek Inventions Brought to Life through Incredible Reconstructions." *Ancient Origins*, Ancient Origins, 4 Aug. 2014, www.ancient-origins.net/news-general/more-fifty-ancient-greek-inventions-brought-life-through-incredible-reconstructions.

Jean Claude Sarl, Chanudet. *Machine for Unstoppering and Emptying Wine Bottles*. 15 Feb. 1991.

Junji, Liu. *Automatic Bottle Pouring Machine*. 25 July 2012.

LifeStyleFancy. "Poursteady Automated Pour over Coffee Machine." *YouTube*, YouTube, 28 Jan. 2015, www.youtube.com/watch?v=76G_KvxsHY4.

Lun, Man Fai. *Electric Wine Opener*. 12 Feb. 2002.

Matt, Samantha. "I Tried the First Ever 'Smart' Keurig for Wine-and This Is What I Thought." *Reviewed.com Smarthome*, 5 Jan. 2017, smarthome.reviewed.com/features/i-tried-the-first-ever-smart-wine-keurig-and-this-is-what-i-thought.

Ravensburg-Weingarten, Hochschule. "KUKA Robot Pours Beer." *YouTube*, YouTube, 4 July 2014, www.youtube.com/watch?v=PgbxjDzjfP8.

Stapleton, Susan. "Go on a Bender at the New Tipsy Robot." *Eater Vegas*, Eater Vegas, 30 June 2017, vegas.eater.com/2017/6/30/15898204/tipsy-robot-now-open.

Tao, Hu. *Cleaning Liquor Pouring out Machine*. 21 Mar. 2012.

WineStuff. "Screwpull S1015-31 Table Corkscrew, Black, Set of 3: Kitchen & Dining."*Screwpull S1015-31 Table Corkscrew, Black, Set of 3: Kitchen & Dining*, Amazon.com, www.amazon.com/Screwpull-S1015-31-Table-Corkscrew-Black/dp/B00MJ1YGY4.

Xiaoyu, Jiang. *Wine Pouring Machine*. 22 Oct. 2008.

Xie, Jun. *Automatic Quantitative Wine Pouring Device*. 10 Oct. 2007.

Zhenzhong, Hu. *Wide-Mouth Bottle Rotary Type Milk Pouring Machine Bottle Overturning Mechanism*. 21 July 2010.

APPENDIX A: SPONSOR INTERVIEW NOTES

<u>Date: September 28, 2017, 10:00am PST</u>

Initial Thoughts:

- Open any of 3 sizes of bottles
- lead foil at top
- pull cork
    - set of specs that covers specs from easiest cork to toughest
    - once cork is pulled, pour a single glass either American or European
    - once one glass is poured, insert another glass
- strain gauges to determine correct content of wine in glass
- null out weight of glass to start with
- traveling wine bottle to various stages
- can provide style of glass and empty bottles
- operate on AC and DC
- should be able to transport
- will be remodeling winery, will have brand new tasting room, interior will be done grays polished stainless, white and gray marble
- Prof. Mase should have the project report information
- Nathan Carlson is the GM at winery
- wait 3 or 4 weeks, will send a concept of what it will look like
    - U-shape tasting bar
    - left hand side living room venue
    - right hand, executive conference room — opener may go here or in back
    - center — demonstration kitchen
    - 50-person board room in back, open room
    - sides: polished, stainless, single rails that pull bottles into different directions
    - minimalistic
    - gray/silver, stainless palette
    - 3-4 weeks should have artist rendition
    - clean lines, nothing ornate
- November may be good to meet at winery, Mr. Swanson will be there
- Corks are different

Questions:

- Yes, will have to deal with wax / wax plastic material
    - corkscrew goes right through, into cork, pull right through material
- spout okay for one of steps
    - consider doing a couple based on what wine is pouring so we don't have to flush
- solid foil capsule
    - almost paper thickness, can be cut with a blade
    - lots of mechanical foil cutters
    - laser pointer in front of cutter to make it look like laser was cutting it for tech look

    - fiber-optic light at base of bottle to light bottle up - futuristic look
- no screw tops
- doesn't need to re-cork
- machine doesn't have to dispose of cork, but if it had reverse capability, corkscrew could spin out
- rabbit: easy wine opener
- wine doesn't need time to breath
- buttons or touch screen preference?
    - up to us — whatever works best
    - smartphone app controller could work well
- glasses: one glass at a time set to pour, or several spaces for several glasses?
    - keep design simple — pour one glass, if need another, put the glass in and hit pour option
    - staging glasses for pouring is too hard
- as we set up controls, dial in feature you want
    - cut foil, pull cork, pour glass
    - may just want to cut foil and pull cork
- can't take too long to run
    - 90 seconds or less is a good amount of time
- figure out how to incorporate COE logo
    - etch logo in stainless?

<u>Date: October 17, 2017, 10:00am PST</u>

- 90 seconds
    - Maximum time
- Interface Control Drawing
    - 3x4 should be smaller
- Timeline
    - Try to accelerate
    - We will do our best to do more prototyping on the front end
- Potential to see the property in November
- Corking machine
    - Nathan probably has one
    - Bill has an old one
    - Plenty of corks and plenty of bottles

<u>Date: January 18, 2018, 10:00am PST</u>

Topics of Discussion

- Gripper
    - Bottle neck collar should be adjustable up and down
- Housing
- CDR Scheduling
- Emailing Nathan again for supplies

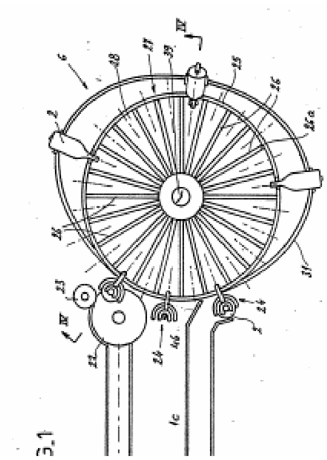
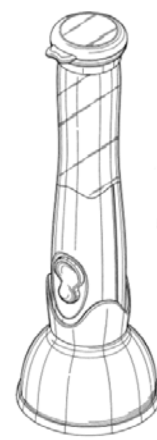
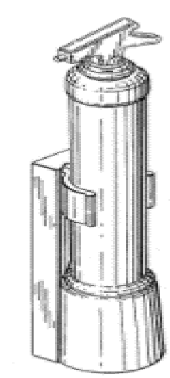
Meeting Minutes

- Email Cheryl for date for CDR
    - Bill in town February 12-17th
    - 13th?
- Concerned about lengths of neck
    - Adjust clamp to base of neck, closer the better
- Recess/indent for glass so it doesn't move
    - Does not need to be exact size
    - Mark it for the server
- Housing
    - Cylinder is good
    - Okay to leave foil cutter and corkscrew?
    - Base with angle is good
- Foil Cutting
    - Concerned about foil coming off with the cutter or having someone remove it manually
    - Find a way to release the foil
    - Button to release foil, not necessary for automatic release
- Cork
    - Button to release cork as well
- Motor in place for bottle rotation
    - Possibly send bill new solid model with motor
    - Concerned about motor torque
    - Center of Effort wine bottles heavier than normal?
- Front panel
    - Develop layout
    - Send choices to bill
- Gripping
    - Good design
    - Do not want bottle shifting in vertical direction
    - Need testing on wet bottles
    - Slide at the neck?
        - Doesn't want holes to show
- Getting supplies
    - Email Nathan and CC Bill

APPENDIX B: FINALIZED WANTS & NEEDS LIST

Spec #	Customer Needs	Customer Wants
1	AC/DC Power	Clean Lines -- Sharp Aesthetic Appeal
2	Plug into Wall	Operate in Under 90 Seconds
3	Operate on Battery Power	Center of Effort Logo Incorporated
4	Fit on a Table Top	Use a Traditional Corkscrew to Remove Cork
5	Automated	Must not Change Temperature of Wine Bottle
6	Secure Multiple Types of Bottles of Wine	Stainless Steel or Black Material
7	Remove Foil from a Bottle of Wine	Do not Pour Wine through a Medium
8	Pour a Bottle of Wine into Multiple Types of Glasses	Futuristic / Modern Aesthetic
9	Pour a Second Glass of Wine	Weather Resistant (Rain)
10	Uncork all Varieties of Corks and Bottles	Easily Accessible / Replaceable Tools
11	Controlled Cork Removal -- No Flying Corks	$4500 Budget
12	Pour a Variety of Pours	Final Prototype by 2nd Week of Winter Quarter
13	Keep Customer's Attention	Final Product by Start of Spring Quarter
14	Strong Enough to Lift a Bottle of Wine and Pour a Glass of Wine	Product should be reproducible (able to make more in the future)
15	Bottle must Remain Intact -- No Broken Glass	
16	Should not Need to be Cleaned between Uses	
17	User Interface with Multiple Options	
18	Safe / Child Proof	
19	Meets Anthropomorphic Specifications	
20	Must Rest on a Flat Foundation	
21	Transportable	
22	Quiet Enough for a Wine Room Setting	
23	Weather Resistant (Sun, Wind)	
24	Deliver a Finished Product	

APPENDIX C: INITIAL PATENT SEARCH FINDINGS

Patent Number	Patent Title	Description	Drawing
FR2650816A1	Machine for unstopping and emptying wine bottles (Jean Claude Sarl, Chanudet)	This is a patent that uses a corkscrew, a motorized endless belt that conveys the bottles, empties the contents into a funnel connected to a reservoir and then collects and organizes the bottles.	
US D453453 S1	Electric wine opener (Lun)	The ornamental design for an electric wine opener, as shown and described.	 FIG. 1
US D303203 S	Combination corkscrew and stand (Chow)	A patent for an electric wine opener with charging stand.	 FIG. 1.

Patent Number	Patent Title	Description	Drawing
CN202346427U	Automatic bottle pouring machine (Junji)	An automatic bottle pouring machine uses a matching device used for the cleaning of glass bottles. It is comprised of a machine frame, a bottle pouring conveying device arranged on the machine frame, an annular bottle pouring conveying belt, and a track, respectively arranged on the left and right sides of the bottle pouring conveying belt. Two chain shafts are arranged in parallel on the machine frame. The left and right ends of each chain shaft are respectively connected with a chain wheel. Two chain wheels arranged on the left and right sides of the bottle pouring conveying belt are respectively connected through a chain. The front face of each chain is provided with a plurality of claw seats. Each claw seat is connected with a chain plate, and each chain plate is connected with the corresponding chain.	N/A
CN201530481U	Wide-mouth bottle rotary type milk pouring machine bottle overturning mechanism (Zhenzhong)	This patent discloses a wide-mouth bottle rotary type milk pouring machine that has a bottle overturning mechanism, which is comprised of a framework platform and a rotary disc. The rotary disc is arranged above the framework platform and driven to rotate via a spindle. A bottle overturning guide track is fixed on the framework platform. A plurality of bottle holding devices capable of overturning are uniformly disposed on the rotary disc peripherally; overturning of the bottle holding devices is controlled by the bottle overturning guide track. Each bottle holding device is comprised of a guide column, a fixing base, and a bottle supporting device. The guide column is engaged with the bottle overturning guide track. The fixing base is fixedly connected with the rotary disc. The bottle supporting device is comprised of a bottle supporting plate for placing a wide-mouth bottle and a connecting plate which is perpendicularly fixedly connected to one end on one side of the bottle supporting plate.	N/A

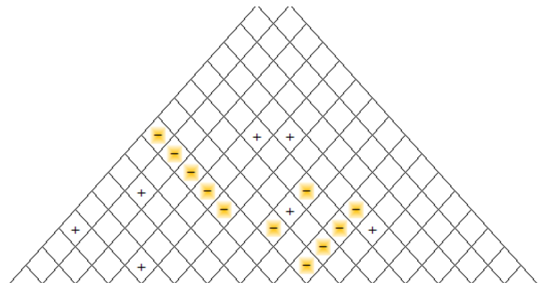
Patent Number	Patent Title	Description	Drawing
CN201136782Y	Wine Pouring Machine (Xiaoyu)	This patent shows a machine that has an inlet with a lock joint that connects to a wine bottle opening and an outlet so that the wine can be spilled out. The bottle pourer main body is shaped like a sphere; the inner wall of the main body has a blocking part which is used for slowing down the flow velocity of the wine liquid. Further, the main body also has a seat with a base and a settlement piece used for shelving an inlet manifold.	N/A
CN200958042Y	Automatic quantitative wine pouring device (Xie)	This fully automatic wine pouring machine is comprised of a wine pouring plastic piston and an outlet pipe. The utility model is characterized by the following: it is comprised of a wine pouring auto control module which can control the outlet pipe to extract fixed amount of wine, wherein, the wine pouring auto control module is comprised of a poking switch which provides the CPU procedure with IC time tap position to set the needed amount of wine to be extracted. The control panel circuit drives the motor to extract wine with an outlet pipe at fixed times and also has an air inlet hole which is communicated with the atmosphere.	N/A
CN101343029B	Cleaning Liquor pouring out machine (Tao)	The invention disclosed is a cleaning and wine filling machine which is comprised of a cleaning box and a wine filling device. The wine filling device uses a wine guide tube and a wine container. The wine filling device is threaded through the guide inlet hole of the cleaning box and the wine guide tube is connected with the wine inlet opening of the wine container. The wine container is mounted on the box wall of the cleaning box through a support. A support separator plate is arranged in the cleaning box. A pipeline guide hole is arranged on the support separator plate. A wine cup containing device is arranged under the cleaning box. The wine cup placing device is comprised of a clamp rack, a wine cup base, and a drive device. The wine cup base is arranged in the clamp rack. One end of the clamp rack is provided with a connecting shaft, which is threaded through the pipeline guide hole of the support separator plate to be connected with the drive device on the other side of the support separator plate. The wine outlet of the wine container is positioned exactly above the wine cup base.	N/A

APPENDIX D: QFD HOUSE OF QUALITY

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

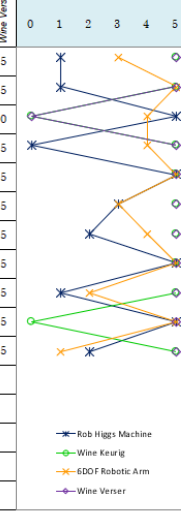
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



					Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	WHO: Customers				Direction of Improvement	▼	▼	▲	◇	▼	▼	▼	▼	▼	▲	◇	▲	▼			
Row #	Weight Chart	Relative Weight	Bill Swanson	Maximum Relationship	HOW: Engineering Specifications / WHAT: Customer Requirements (explicit & implicit)	Product Width	Cork Pull Force	Lifting Force	Product Weight	Height of Robot	Noise Measurement	Operation Time	Change in Wine Temp throughout operation	Cost	# of Cork and Foil Removals on one charge	poured wine volume accuracy	Number of pours on one charge	Product Depth			
1	IIIII	10%	4	9	Fits on a Table Top	●			▽									●			
2	IIIIII	13%	5	9	Run long enough to pour a case of wine		▽	▽				▽			●		●				
3	IIIIII	13%	5	9	Can Uncork All Varieties of Corks/Bottles		●														
4	III	8%	3	9	Pour a variety of Volumes											●					
5	II	5%	2	9	Meets Anthropromorphic Specs	▽			▽	●	▽							▽			
6	III	8%	3	9	Quiet Enough for Tasting Room		▽				●										
7	IIIII	10%	4	9	Fast Enough to Keep Customer Attention		▽	▽				●				○					
8	III	8%	3	9	Must Not Change Wine Temp								●								
9	I	3%	1	9	Keep Within Budget ($4000)		▽	▽						●							
10	IIIIII	13%	5	9	Strong Enough to Lift Wine			●													
11	IIIII	10%	4	9	Portable	○			●	○								○			
12		0%																			
13		0%																			
14		0%																			
15		0%																			
16		0%																			
					HOW MUCH: Target	Less than 36 inches Wide	Pull Force of at least 40 N	Able to lift a 4 lb bottle	Weighs between 5 and 50 lbs	between 1 and 4 feet tall	Peak noise level less than 70 decibels	Operation time less than 120 seconds	Temperature of wine changes less than 5 degrees fahrenheit	Cost less than $4000	12 foil and cork removals	Pour a 5 ounce wine accurately to within 5 percent	150 pours on one charge	Less than 48 Inches Deep			
					Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9	9			
					Technical Importance Rating	128.2	148.7	141	107.7	76.92	74.36	105.1	69.23	23.08	115.4	100	115.4	128.2			
					Relative Weight	10%	11%	11%	8%	6%	6%	8%	5%	2%	9%	8%	9%	10%			

NOW: Current Product Assesment - Customer Requirements

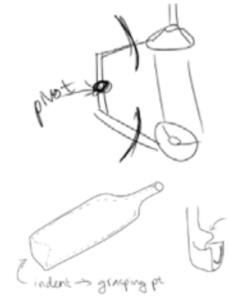
Row #	Rob Higgs Machine	Wine Keurig	6DOF Robotic Arm	Wine Verser
1	1	5	3	5
2	1	5	5	5
3	5	0	4	0
4	0	5	4	5
5	5	5	5	5
6	3	5	3	5
7	2	5	4	5
8	5	5	5	5
9	1	5	2	5
10	5	0	5	5
11	2	5	1	5
12				
13				
14				
15				
16				

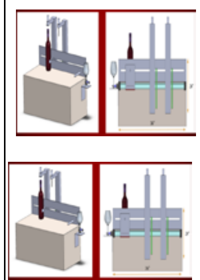
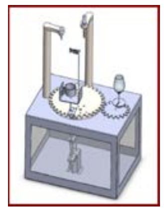
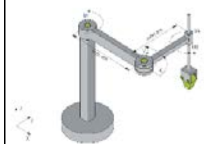
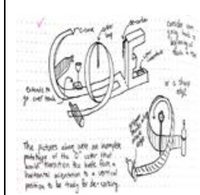
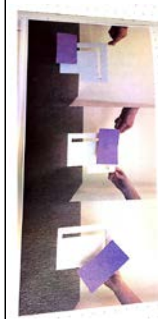


APPENDIX E: WEIGHTED DECISION MATRICES

Cork Removal	Weighting	Pull Corkscrew	Waiters Helper	Rabbit	Electric Corkscrew
Image Concept					
Time of Removal	*2*	4	4	5	4
Ease of Alignment	*5*	4	4	5	5
Force on Bottle	*5*	1	3	5	5
Motor Integration	*5*	4	2	1	5
TOTALS		53	53	65	**83**

User Interface	Weighting	Levers/Switches	Dials	Buttons (General)	Touch Screen	App	Remote Control
Image Concept							
Aesthetic	*2*	3	4	3	5	5	1
Feedback	*3*	5	5	4	5	5	1
Feasibility	*5*	5	5	5	4	2	1
TOTALS		46	**48**	43	45	35	10

Gripping	Weighting	Rotating Claw	Hose Clamp	Linear Claw Gripper	Inflatable Cushion	Bottle Handle	Top Funnel/Base Plug	Broom Clip
Image Concept								
Aesthetic Appeal	*2*	5	2	4	3	3	3	5
Ease of Integration with Other Actions	*4*	5	5	5	3	5	5	5
Lifting Force	*5*	5	5	5	5	5	5	5
Design Feasibility	*4*	3	5	4	2	5	2	5
Reliability (how hard is it to mess up)	*5*	3	5	4	5	5	3	5
TOTALS		82	94	89	76	96	74	**100**

Lifting/ Pouring	Weighting	Linear Actuator Stations	Rotating Platform Stations	Robot Arm - SCARA	4 Bar Linkage	C-Curve Pour	Linear Lift & Rotational Pour	Escalator
Image Concept								
aesthetic	*2*	3	4	4	3	5	2	2
ease of integration	*5*	5	5	5	4	2	3	4
design feasibility	*4*	5	5	4	5	4	5	5
reliability	*4*	5	5	3	5	4	5	5
size of device	*3*	1	1	3	5	3	4	3
operation time	*3*	5	5	5	4	5	5	5
spillage	*4*	4	4	5	4	4	5	4
TOTALS		105	107	105	**109**	92	106	104

Sense Weight	Weighting	Flowrate and Timer	Scale	Load Cell/ Strain Gauge	Pressure Sensor	Mechanical Pour Regulator
Image Concept						
Accuracy	*5*	1	4	5	4	5
Size	*3*	5	2	3	5	3
Aesthetic	*2*	5	3	4	5	2
Ease of Implementation	*5*	1	3	4	5	1
Ease of Automation	*5*	5	4	5	5	1
TOTALS		60	67	87	**95**	48

Remove Foil	Weighting	Scrape Tools	1 Bladed Cutter	2 Bladed Cutter
Image Concept				
Clean cut	2	1	5	5
Reliability	5	1	3	5
Ease of Alignment	5	1	3	5
Cutting Speed	5	5	4	4
TOTALS		8	15	**19**

Appendix E

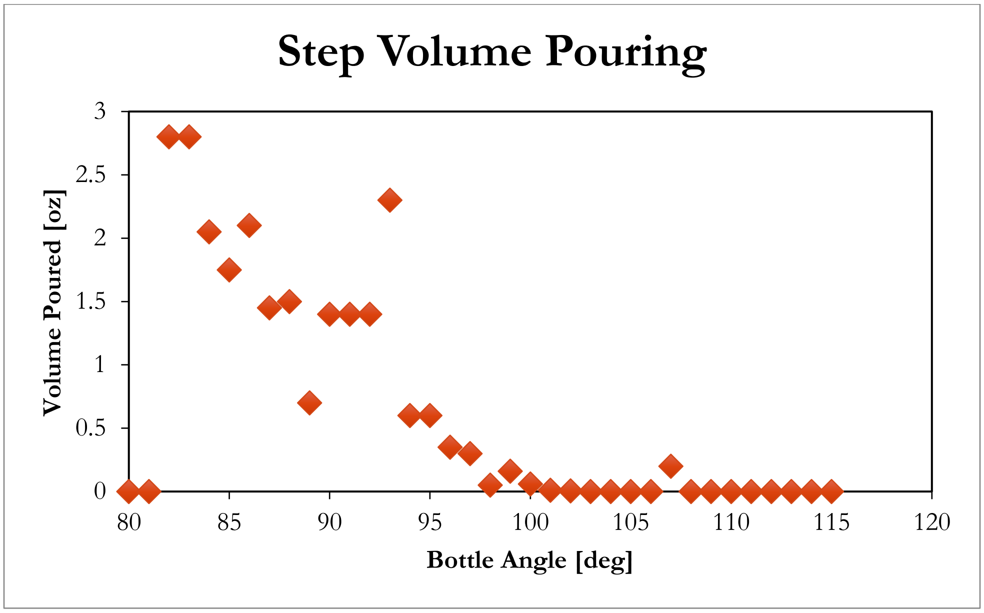
APPENDIX F: BOTTLE POUR ANGLES

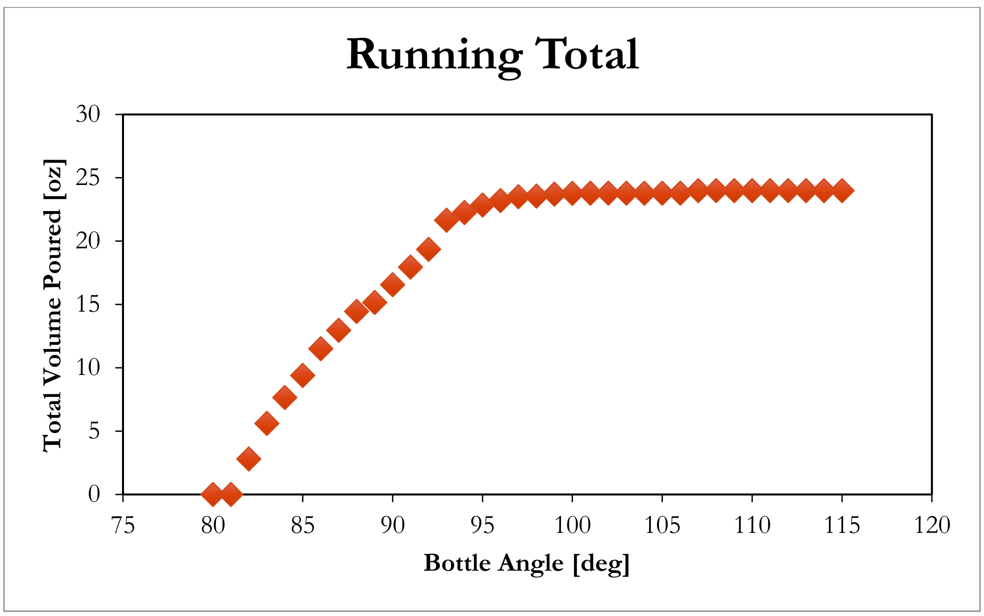
Testing Pour Angle and Flow Rate from a Wine Bottle and Results

These tests were performed by tilting a full wine bottle in one-degree increments and recording the amount of liquid that poured out as a result.

Bottle	Ounce/Degree			Total Volume Poured [oz]		
Angle	**Trial 1**	**Trial 2**	**Avg**	**Trial 1**	**Trial 2**	**Avg**
80	0	0	0	0	0	0
81	0	0	0	0	0	0
82	0	5.6	2.8	0	5.6	2.8
83	3.5	2.1	2.8	3.5	7.7	5.6
84	2.2	1.9	2.05	5.7	9.6	7.65
85	1.9	1.6	1.75	7.6	11.2	9.4
86	2.2	2	2.1	9.8	13.2	11.5
87	1.1	1.8	1.45	10.9	15	12.95
88	1.6	1.4	1.5	12.5	16.4	14.45
89	1.1	0.3	0.7	13.6	16.7	15.15
90	1.3	1.5	1.4	14.9	18.2	16.55
91	1.1	1.7	1.4	16	19.9	17.95
92	1.4	1.4	1.4	17.4	21.3	19.35
93	2.8	1.8	2.3	20.2	23.1	21.65
94	0.8	0.4	0.6	21	23.5	22.25
95	1.1	0.1	0.6	22.1	23.6	22.85
96	0.6	0.1	0.35	22.7	23.7	23.2
97	0.5	0.1	0.3	23.2	23.8	23.5
98	0.1	0	0.05	23.3	23.8	23.55
99	0.02	0.3	0.16	23.32	24.1	23.71
100	0.02	0.1	0.06	23.34	24.2	23.77
101	0.02	0	0.01	23.36	24.2	23.78
102	0.01	0	0.005	23.37	24.2	23.79
103	0	0	0	23.37	24.2	23.79
104	0	0	0	23.37	24.2	23.79
105	0	0	0	23.37	24.2	23.79
106	0	0	0	23.37	24.2	23.79
107	0.4	0	0.2	23.77	24.2	23.99
108	0	0	0	23.77	24.2	23.99
109	0	0	0	23.77	24.2	23.99
110	0	0	0	23.77	24.2	23.99

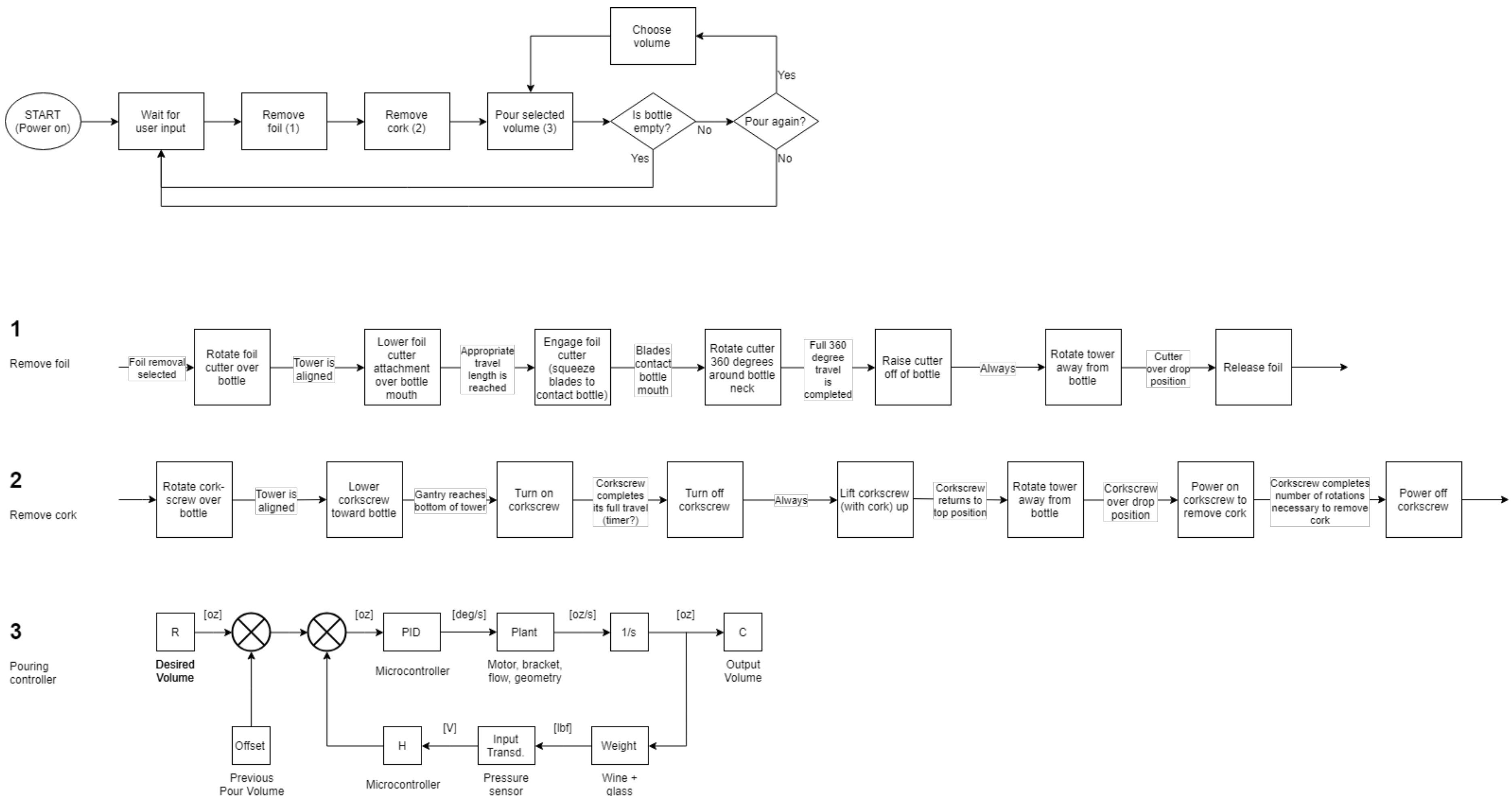
<u>Testing Pour Angle and Flow Rate from a Wine Bottle and Results</u>





APPENDIX G: SOFTWARE PLANNING

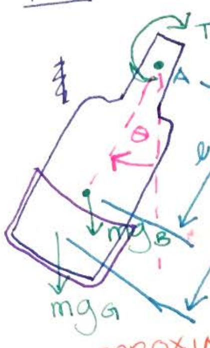
Master State Diagram and Sub-state Diagrams



APPENDIX H: PRELIMINARY ANALYSIS

Calculations concerning Prototype Modes of Failure

FBD



$$\circlearrowleft + \Sigma M_A = 0 \quad \text{(STATIC)}$$

$$-T + (mg)_B l_B + (mg)_G l_G = 0$$

$$T = m_B g l_B + m_G g l_G$$

$$T = g(m_B l_B + m_G l_G)$$

∴ * THIS IS A SIMPLIFIED MODEL

* ASSUMPTIONS:

APPROXIMATED { − CENTER OF GRAVITY FOR THE BOTTLE
− CENTER OF GRAVITY FOR BASE

− $l_B \approx 8\text{in}$ − $l_G \approx 10\text{in}$

(INCREASE THESE VALUES FOR A MORE EXTREME CASE)

− $m_B \approx 3.5\,\text{lbm}$ − $m_G \approx 2\,\text{lbm}$

$$T = \left(32.174 \frac{ft}{s^2}\right)\left[\left(3.5\,\cancel{lbm} \times \frac{1\,\cancel{slug}}{32.174\,\cancel{lbm}} \times \frac{1\,lbf}{1\,\cancel{slug}\,\cancel{ft}/s^2}\right)\left(8\,\cancel{in} \times \frac{1\,ft}{12\,\cancel{in}}\right) + \left(2\,\cancel{lbm} \times \frac{1\,\cancel{slug}}{32.174\,\cancel{lbm}} \times \frac{1\,lbf}{1\,\cancel{slug}\,\cancel{ft}/s^2}\right)\left(10\,\cancel{in} \times \frac{1\,ft}{12\,\cancel{in}}\right)\right]$$

$$T = \left(32.174 \frac{ft}{\cancel{s^2}}\right)\left[0.07252\ lbf\,\cancel{s^2} + 0.05180\ lbf\,\cancel{s^2}\right]$$

$$T = 4.067\ \cancel{lbf}\cdot\cancel{ft} \times \frac{12in}{1\,\cancel{ft}} \times \frac{16oz}{1\,\cancel{lbf}}$$

$$\boxed{T = 780.9\ oz\text{-}in}$$

* THIS IS AN APPROXIMATE REQUIRED TORQUE NEEDED TO ROTATE THE BOTTLE AT THE SHOWN LOCATION.

* THE SPEC FOR THE CURRENT MOTOR THAT WE HAVE IS 6N·m WHICH CONVERTS TO ≈850 oz-in

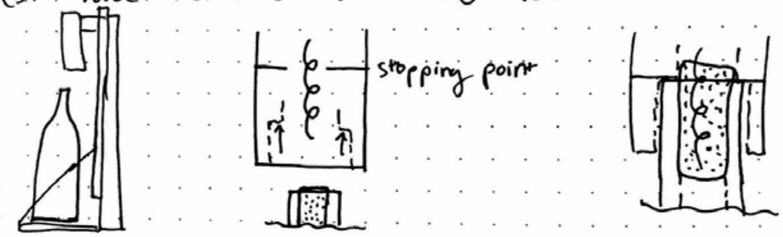
↳ THE FACTOR OF SAFETY WILL BE FAIRLY LOW IF THE ASSUMED VALUES ARE CORRECT.

Calculations concerning Rotating Tower Forces

11/8/2017

Tower Torque Calculation

From previous group's report finding with cork pull forces, the greatest force exerted was 40 lbs.

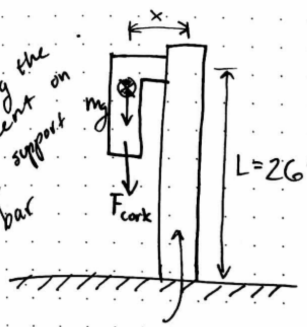


11/8/2017

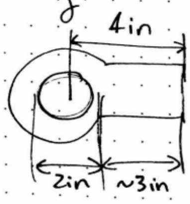
PDR

Idea Evaluation: Will it work?
Calculations, additional modeling, etc.

Finding the moment on the support bar



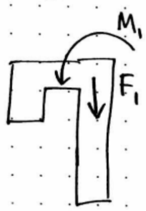
we are concerned about this piece bending



$mg = 1.2$ lbs

rounding to 1.5 pounds to include weight of attachment structure.

$mg + F_{cork} = 41.5$ lbs $= F_1$



$M_1 = F_1 x$

$x \approx 4in$

$M_1 = (41.5 \text{ lbs})(4 \text{ in})$

$\boxed{M_1 = 166 \text{ in-lbs}}$

My team split up the calculations as shown on the previous page and I will document more after I recieve the results from my team-mates tomorrow in class.

As described on page 43, we have proven that the motions for pouring the bottle and for de-corking will work. As for the other functions, we are currently purchasing a foil cutter and small linear actuators to prototype with, as well as some gripper mechanisms to hold the bottle in place on the linkage. We also are purchasing 2 devices to work with for measuring the volume of wine poured in the glass and will start testing their validity once they arrive. These are the pressure sensor and the load cell.

Appendix I: Complete Drawings Packet

*Note: Parts designed so they do not require GD&T precisior

Custom/Modified Parts:

Drawings/Spec Sheets Not Attached:

Bill of Materials

Assy Level	Drawing Number	Description	Material	Vendor	Qty	Cost	Total Cost
		Lvl0 Lvl1 Lvl2					
0	A100	Wine Project Assembly	-----	------	------	------	$ 3,048.64
1	B100	Pouring Mechanism	------	------	1	$ 791.00	$ 1,064.90
2	B101	Custom L Bracket	Aluminum	McMaster Carr	1	$1.05	$ 1.05
2	B102	Linear Rail Base V-slot	Aluminum	Open-Builds	1	$ 16.50	$ 16.50
2	B103	Black Angle Corner Connector	Aluminum	Open-Builds	4	$ 2.75	$ 11.00
2	B104	Gripper Backbone	1.25x1.25x12" Alum Bar	McMaster Carr	1	$ 3.33	$ 3.33
2	B105	MX-64T (Pouring Motor)	MOTOR	RobotShop	1	$ 360.00	$ 360.00
2	B106	Custom Screw Insert	3/8" Alum Rod	McMaster Carr	2	$ 0.18	$ 0.36
2	B107	Bottle Sleeve Holder Curve	Aluminum	McMaster Carr	1	$ 164.09	$ 164.09
2	B108	Thumb screw	FASTENER	McMaster Carr	2	$ 4.23	$ 8.46
2	B109	Bottle Sleeve	Acrylic	TAP Plastics	1	$ 10.00	$ 10.00
2	B110	Neck Clamp	CLAMP	STAFFORD Mfg	1	$ 117.21	$ 117.21
2	B111	Bottle Sleeve Punt Grip	3D Print	Shapeways	1	$ 25.00	$ 25.00
2	B112	Fastener Combination	FASTENER	Open-Builds	32	$ 0.32	$ 10.24
2	B114	Neck Clamp Rubber Insert	Rubber	Fictiv	2	$ 76.10	$ 152.20
2	B115	Pouring Motor Spacer	1/4" Aluminum	McMaster Carr	1	$ 5.63	$ 5.63
2	B116	Finger Shield	Acrylic	McMaster Carr	1	$ 4.61	$ 4.61
2	B117	Bottle Sleeve Base	Acrylic	McMaster Carr	1	$ 2.12	$ 2.12
2	B118	Pouring Housing	Aluminum Round Tube	McMaster Carr	1	$ 109.45	$ 109.45
2	B119	Pouring Housing Cap	Aluminum	McMaster Carr	1	$ 3.67	$ 3.67
2	B120	Pouring Housing Cover	Aluminum Sheet	McMaster Carr	1	$ 59.98	$ 59.98
2	B121	Rubber Screw Caps	Rubber	McMaster Carr	2	$0.08	$ 0.16
1	B200	Tower	------	------	------	------	$ 408.26
2	B201	Pattern Mount Plate Top	Aluminum	McMaster Carr	1	$ 23.00	$ 23.00
2	B202	Turntable Bearing	BEARING	McMaster Carr	1	$ 10.71	$ 10.71
2	B203	AX-12A (Turntable Motor)	MOTOR	RobotShop	1	$ 44.90	$ 44.90
2	B204	L Bracket Single	Aluminum	Open-Builds	5	$ 1.00	$ 5.00
2	B205	2-Hole Connecting Bracket	Aluminum	McMaster Carr	1	$ 4.88	$ 4.88
2	B206	Linear Tower Assembly	LINEAR ACTUATOR	Open-Builds	1	$ 138.05	$ 138.05

Appendix I: Complete Drawings Packet

*Note: Parts designed so they do not require GD&T precisior

Custom/Modified Parts:

Drawings/Spec Sheets Not Attached:

Bill of Materials

Assy Level	Drawing Number	Description	Material	Vendor	Qty	Cost	Total Cost
		Lvl0 Lvl1 Lvl2					
2	B207	V-Slot Gantry Set	WHEELS	Open-Builds	1	$ 43.55	$ 43.55
2	B208	Tower Housing Cap	Aluminum	McMaster Carr	1	$ 16.17	$ 16.17
2	B209	Tower Housing Ring	Aluminum	McMaster Carr	1	$ 8.29	$ 8.29
2	B210	Tower Housing Tube	Aluminum	McMaster Carr	1	$ 77.86	$ 77.86
2	B211	Limit Switch	LIMIT SWITCH	McMaster Carr	1	$ 8.88	$ 8.88
2	B212	Vibration Damping Washers	Polyurethane Rubber	McMaster Carr	9	$ 0.31	$ 2.79
2	B103	Black Angle Corner Connector	Aluminum	Open-Builds	6	$ 2.75	$ 16.50
2	B112	Fastener Combination	FASTENER	Open-Builds	24	$ 0.32	$ 7.68
1	B300	Floating Gantry Subassembly	------	------	------	------	$ 132.20
2	B301	Plates with Mounting Holes	Aluminum	McMaster Carr	2	$ 11.99	$ 23.98
2	B113	Fastener Combination	FASTENER	Open-Builds	16	$ 0.32	$ 5.12
2	B204	L Bracket Single	Aluminum	Open-Builds	16	$ 1.00	$ 16.00
2	B207	V-Slot Gantry Set	GANTRY	Open-Builds	2	$ 43.55	$ 87.10
1	B400	Foil Cutter Subassembly	------	------	------	------	$ 334.10
2	B401	Foil Cutter Bottom Cap	3x3x1/8"	McMaster Carr	1	$ 8.29	$ 8.29
2	B402	Foil Cutter Linear Servo	MOTOR	RobotShop	2	$ 65.00	$ 130.00
2	B403	Foil Cutter Holder	3D Print	Shapeways	2	$ 19.00	$ 38.00
2	B404	Foil Cutter Rail	Acrylic	McMaster Carr	1	$ 2.24	$ 2.24
2	B405	Serrated Blade	FOIL CUTTER	Amazon	2	$ 2.50	$ 5.00
2	B406	Fastener Combination	M3 FASTENER AND NUT	Open-Builds	6	$ 0.32	$ 1.92
2	B407	Fastener	M2 FASTENER	McMaster Carr	8	$ 0.32	$ 2.56
2	B408	Fastener Combination	M2 FASTENER AND NUT	RobotShop	8	$ 0.32	$ 2.56
2	B409	Foil Cutter Housing	Aluminum	McMaster Carr	1	$ 37.24	$ 37.24
2	B410	Foil Cutter Housing Cap	Aluminum	McMaster Carr	1	$ 8.46	$ 8.46
2	B411	Foil Cutter Housing Cover	Aluminum	McMaster Carr	1	$ 2.55	$ 2.55
2	B412	Foil Arm Housing	Aluminum Square Tube	McMaster Carr	2	$ 8.21	$ 16.42
2	B413	Foil Cutter Top Cap	Aluminum	McMaster Carr	1	$ 5.52	$ 5.52
2	B414	Foil Cutter Motor Plate	Aluminum	McMaster Carr	1	$ 3.94	$ 3.94
2	B102	Linear Rail Base V-slot	Aluminum	Open-Builds	1	$ 16.50	$ 16.50

Appendix I: Complete Drawings Packet

*Note: Parts designed so they do not require GD&T precisior

Custom/Modified Parts:

Drawings/Spec Sheets Not Attached:

Bill of Materials

Assy Level	Drawing Number	Description (Lvl0 / Lvl1 / Lvl2)	Material	Vendor	Qty	Cost	Total Cost
2	B203	Dynamixel AX-12A	MOTOR	RobotShop	1	$ 44.90	$ 44.90
2	B204	L Bracket Single	Aluminum	Open-Builds	8	$ 1.00	$ 8.00
1	B500	Cork Remover	------	------	------	------	$ 55.18
2	B501	Corkscrew Arm Housing	Aluminum	McMaster Carr	1	$ 4.11	$ 4.11
2	B502	Corkscrew Housing Tube	Aluminum Tube	Online Metals	1	$ 18.28	$ 18.28
2	B503	Corkscrew Housing Top	Aluminum	McMaster Carr	1	$ 2.33	$ 2.33
2	B504	Corkscrew Bottom Cap	Aluminum	McMaster Carr	1	$ 1.99	$ 1.99
2	B505	Electric Corkscrew	CORKSCREW	Target	1	$ 19.99	$ 19.99
2	B506	Fastener Combination	M3 FASTENER AND NUT	RobotShop	6	$ 0.32	$ 1.92
2	B507	Fastener Combination	M5 FASTENER AND NUT	RobotShop	4	$ 0.32	$ 1.28
2	B508	Fastener Combination	M5 FASTENER AND NUT	RobotShop	4	$ 0.32	$ 1.28
2	B204	L Bracket Single	Aluminum	Open-Builds	4	$ 1.00	$ 4.00
1	B600	Electrical box/support	------	------	------	------	$ 970.54
2	B601	Drawer Handles	CHROME PLATED ZINC	Mcmaster Carr	2	$ 6.00	$ 12.00
2	B602	Base Plate	18"x18"x1/4" aluminum	Online Metals	1	$ 68.90	$ 68.90
2	B603	Electrical Box	Sheet Metal	Protocase	1	$ 582.66	$ 582.66
2	B604	Splash Shield Base	Acrylic	McMaster Carr	1	$ 1.33	$ 1.33
2	B605	Splash Shield Support	Acrylic	McMaster Carr	2	$ 2.97	$ 5.94
2	B606	Splash Shield Wall	Acrylic	McMaster Carr	2	$ 2.84	$ 5.68
2	B607	Power Supply - 12V 5A	POWER SUPPLY	RobotShop	1	$ 24.95	$ 24.95
2	B608	Arduino Mega 2560	ARDUINO	Amazon	1	$ 14.99	$ 14.99
2	B609	Foot Pads	FOOT PAD	McMaster Carr	9	$ 0.51	$ 4.56
2	B610	12in Servo Wire Extender	SERVO WIRE	RobotShop	8	$ 1.95	$ 15.60
2	B611	Digital Servo Shield	SERVO	RobotShop	1	$ 24.20	$ 24.20
2	B612	Nylon Standoffs	STANDOFF	McMaster Carr	14	$ 1.97	$ 27.58
2	B613	Load Cell Shield	CELL	RobotShop	1	$ 19.95	$ 19.95
2	B614	Stepper Motor Driver	MOTOR DRIVER	Pololu	1	$ 5.95	$ 5.95
2	B615	Keyswitch	KEYSWITCH	Mouser	1	$ 15.76	$ 15.76
2	B616	Auxiliary Routing Board	PCB BOARD	Oshpark	1	$ 22.40	$ 22.40

Appendix I: Complete Drawings Packet

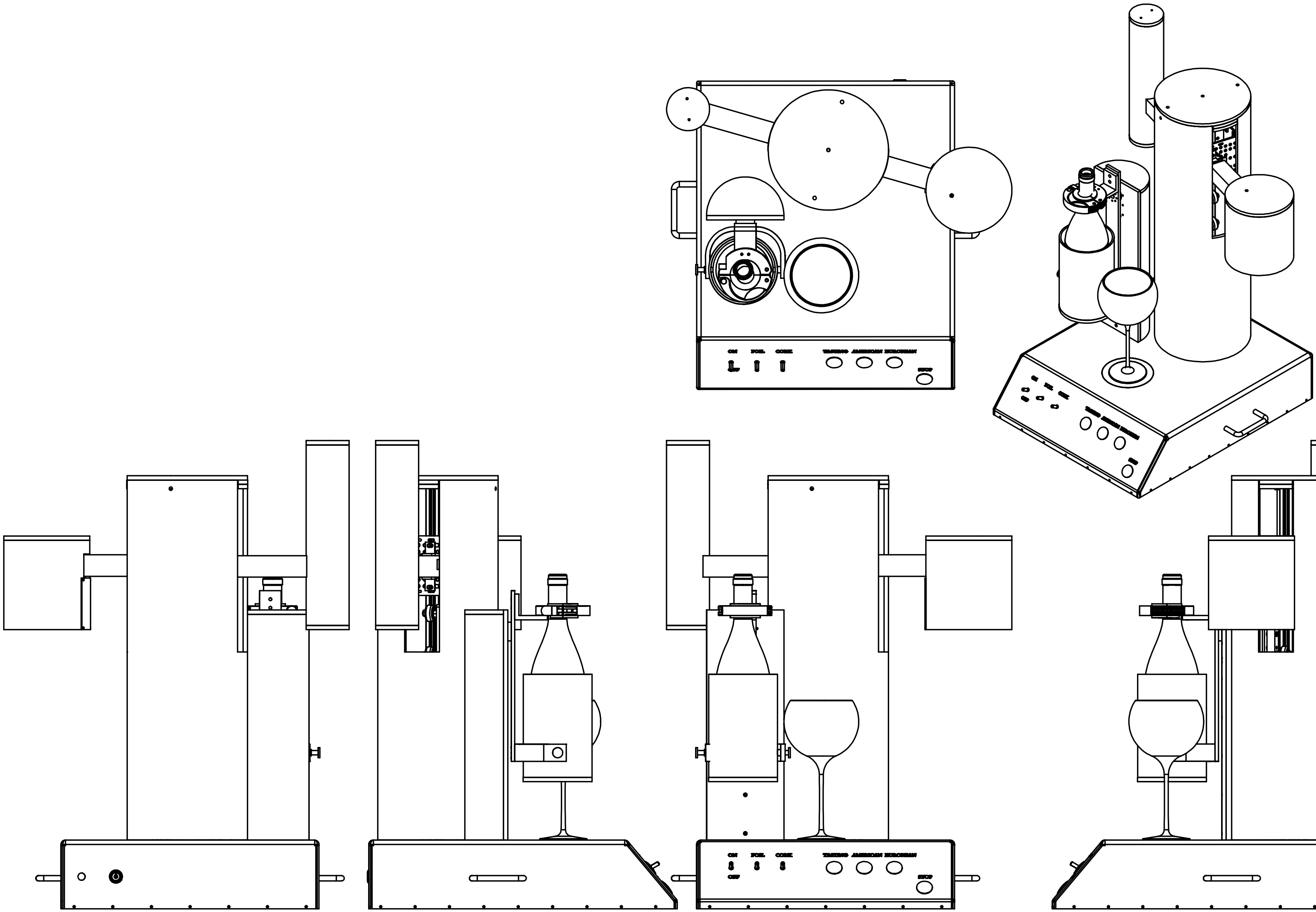
*Note: Parts designed so they do not require GD&T precisior

Custom/Modified Parts:

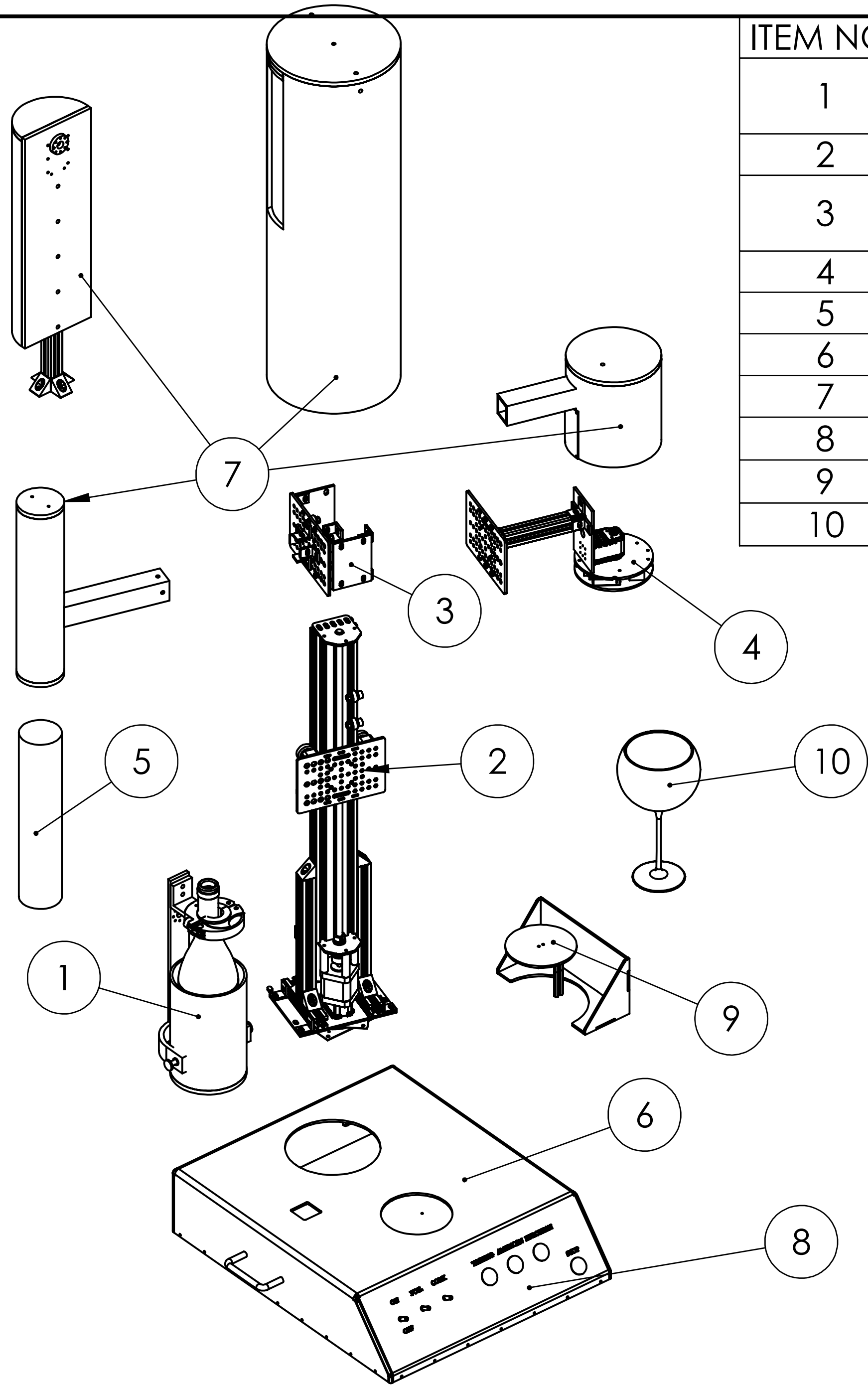
Drawings/Spec Sheets Not Attached:

Bill of Materials

Assy Level	Drawing Number	Description	Material	Vendor	Qty	Cost	Total Cost
		Lvl0 Lvl1 Lvl2					
2	B617	Tri-State Buffer Chip	BUFFER CHIP	Mouser	1	$ 0.86	$ 0.86
2	B618	DC Motor Driver	MOTOR DRIVER	Pololu	1	$ 24.95	$ 24.95
2	B619	Fuse	FUSE	McMaster Carr	1	$ 9.29	$ 9.29
2	B620	Fuse Holder	FUSE HOLDER	McMaster Carr	1	$ 5.08	$ 5.08
2	B621	Barrel Jack	BARREL JACK	Amazon	1	$ 12.99	$ 12.99
2	B622	DC12V to 6V Voltage Converter	VOLTAGE CONVERTER	Amazon	1	$ 9.99	$ 9.99
2	B623	16 Gauge Wire	WIRE per foot	ACE Hardware	18	$ 0.59	$ 10.62
2	B624	18 Gauge Wire	WIRE per foot	ACE Hardware	21	$ 0.59	$ 12.39
2	B625	Wire Nuts	WIRE NUTS	ACE Hardware	8	$ 1.77	$ 14.16
2	B626	Quick Disconnect	QUICK DISCONNECT	ACE Hardware	4	$ 1.44	$ 5.76
2	B627	Metal Standoffs	STANDOFF	McMaster Carr	4	$ 0.44	$ 1.76
2	B113	Fastener Combination	FASTENER	Open-Builds	32	$ 0.32	$ 10.24
1	B700	User Interface Components	------	------	------	------	$ 49.62
2	B701	LED Toggle Switches	TOGGLE	Mouser	3	$ 9.36	$ 28.08
2	B702	Buttons	BUTTON	Digikey	4	$ 1.50	$ 6.00
2	B703	DC Relay Board	LED	Amazon	1	$ 9.59	$ 9.59
2	B704	Wires	JUMPER RIBBON CABLE 15'	RobotShop	1	$ 5.00	$ 5.00
2	B705	5V Voltage Regulator	VOLTAGE REGULATOR	Sparkfun	1	$ 0.95	$ 0.95
1	B800	Weight Sensor Subassembly	------	------	------	------	$ 33.84
2	B801	Load Cell	LOAD	RobotShop	1	$ 7.00	$ 7.00
2	B802	Wine Glass Plate	6x6x1/8" alum.	McMaster Carr	1	$ 9.60	$ 9.60
2	B803	Housing Weight Standoff	STANDOFF	Digikey	2	$ 3.44	$ 6.88
2	B804	Plate Weight Standoff	STANDOFF	Digikey	4	$ 2.50	$ 10.00
2	B805	M3x12 Button Head Cap Screw	FASTENER	McMaster Carr	2	$ 0.18	$ 0.36
				Purchased Parts Total:		$ 3,048.64	



Cal Poly Mechanical Engineering	Material: SEE BILL OF MATERIALS		Title: WINE PROJECT MAIN ASSEMBLY		Drwn. By: JULIA TRENKLE
ME 429 - Winter 2018	Dwg. #:A100	Nxt Asb:NONE	Date:5/30/2018	Scale: 1:8	Chkd. By: BRETT WITTMUSS



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	B100	POURING TOWER	1
2	B200	LINEAR ACTUATOR TOWER	1
3	B300	FLOATING GANTRY SUBASSEMBLY	1
4	B400	FOIL CUTTER	1
5	B500	CORK REMOVER	1
6	B600	ELECTRONICS CONTROL PAD	1
7	B700	HOUSING	1
8	B800	USER INTERFACE	1
9	B900	WEIGHT SENSOR	1
10	--	WINE GLASS	1

NOTES:
SEE SUBASSEMBLY DRAWINGS FOR PART MATERIALS

Cal Poly Mechanical Engineering	Material: SEE BILL OF MATERIALS	Title: WINE PROJECT MAIN ASSEMBLY	Drwn. By:JULIA TRENKLE
SENIOR DESIGN	Dwg. #: A100 / Nxt Asb:NONE	Date:5/30/2018 / Scale:1:10	Chkd. By: BRETT WITTMUSS

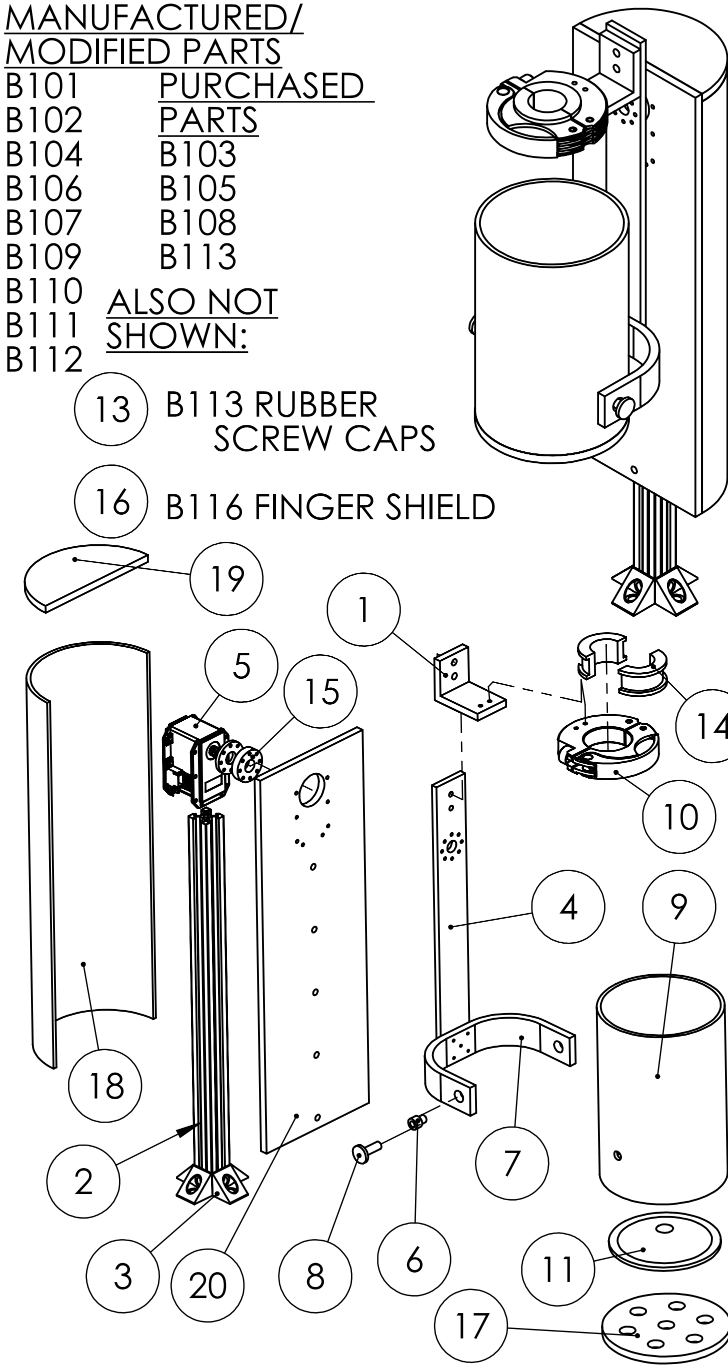
ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B101	CUSTOM L BRACKET	ALUM.	1
2	B102	LINEAR RAIL V-SLOT	ALUM.	1
3	B103	BLACK ANGLE CORNER CONNECTOR	ALUM.	4
4	B104	GRIPPER BACKBONE	ALUM.	1
5	B105	MX-64T (POURING MOTOR)	--	1
6	B106	CUSTOM SCREW INSERT	ALUM.	2
7	B107	BOTTLE SLEEVE HOLDER CURVE	ALUM.	2
8	B108	THUMB SCREW	--	2
9	B109	BOTTLE SLEEVE	CLEAR ACRYLIC	1
10	B110	NECK CLAMP	--	1
11	B111	BOTTLE SLEEVE PUNT GRIP	NYLON	1
12	B112	FASTENER COMBINATION	--	17
13	B113	RUBBER SCREW CAPS	--	2
14	B114	NECK CLAMP RUBBER INSERT	RUBBER	2
15	B115	POURING MOTOR SPACER	ALUM.	2
16	B116	FINGER SHIELD	ACRYLIC	1
17	B117	BOTTLE SLEEVE BASE	ACRYLIC	1
18	B118	POURING HOUSING	ALUM.	1
19	B119	POURING HOUSING CAP	ALUM.	1
20	B120	POURING HOUSING COVER	ALUM.	1

12 PARTS NOT SHOWN:
B103 FASTNER COMBINATION:
TEE NUT & M5 8mm SCREW FOR ALL EXCEPT FOR:
5 M5 5mm SCREW FOR POURING HOUSING COVER
2 M3 12mm SCREW FOR NECK CLAMP

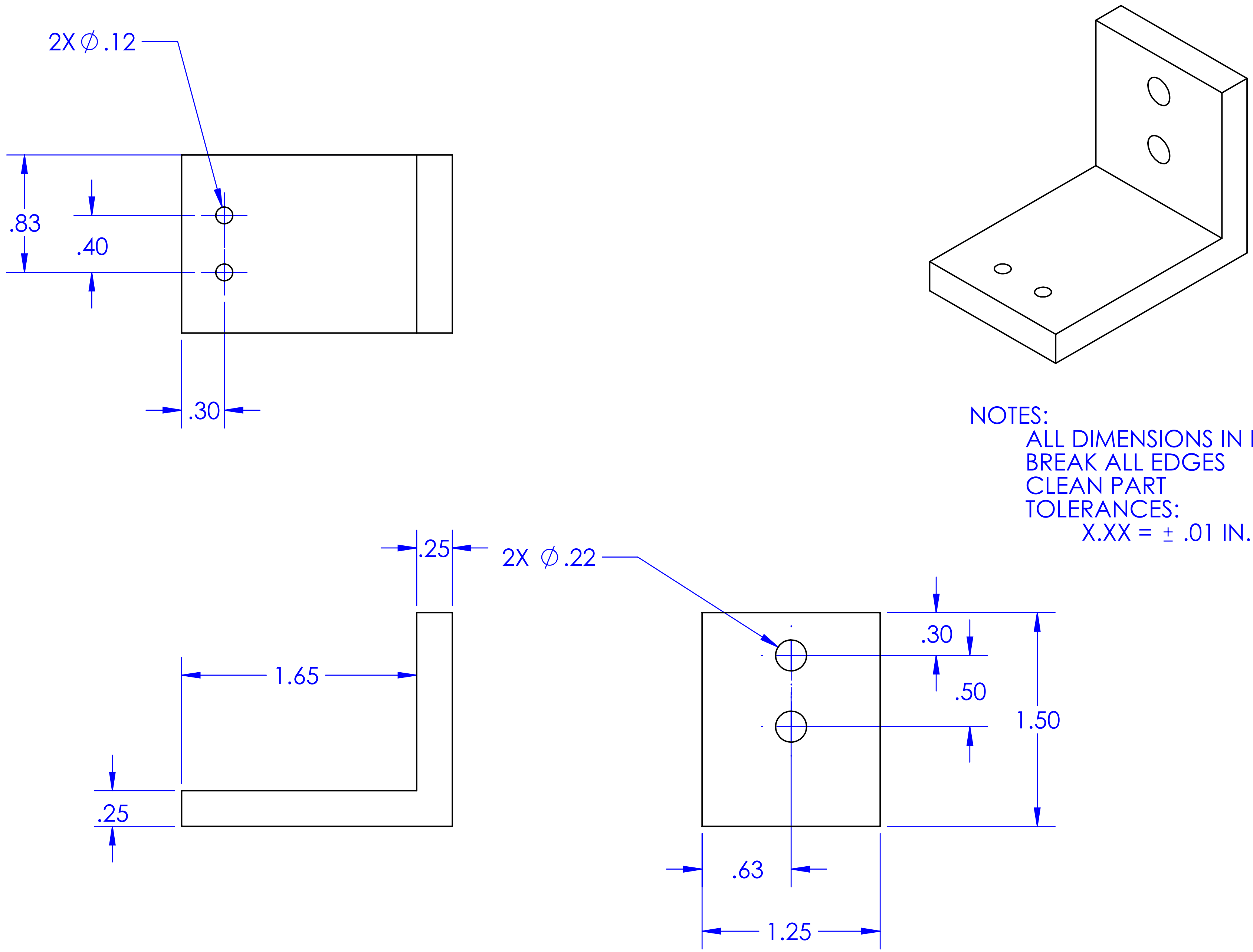
MANUFACTURED/ MODIFIED PARTS
B101
B102
B104
B106
B107
B109
B110
B111
B112

PURCHASED PARTS
B103
B105
B108
B113

ALSO NOT SHOWN:
13 B113 RUBBER SCREW CAPS
16 B116 FINGER SHIELD

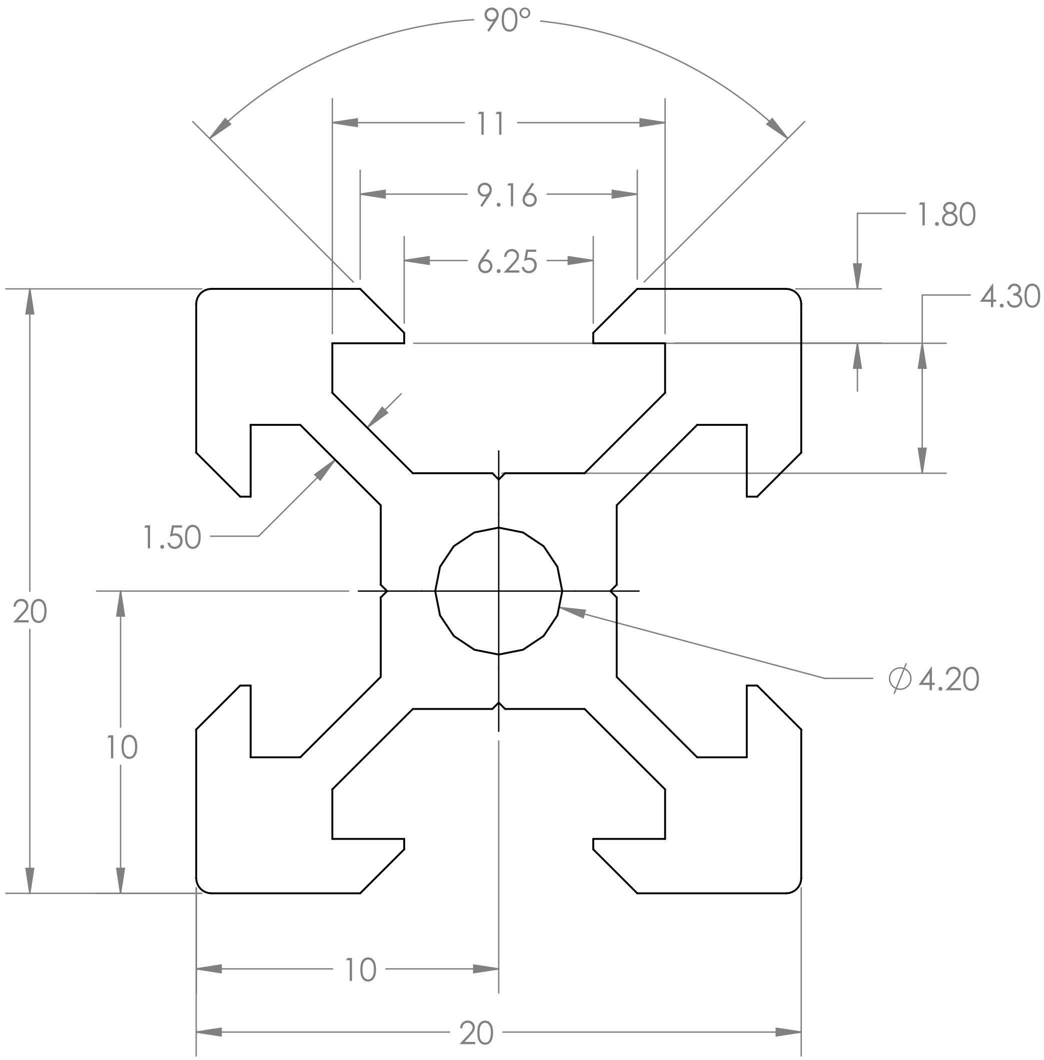


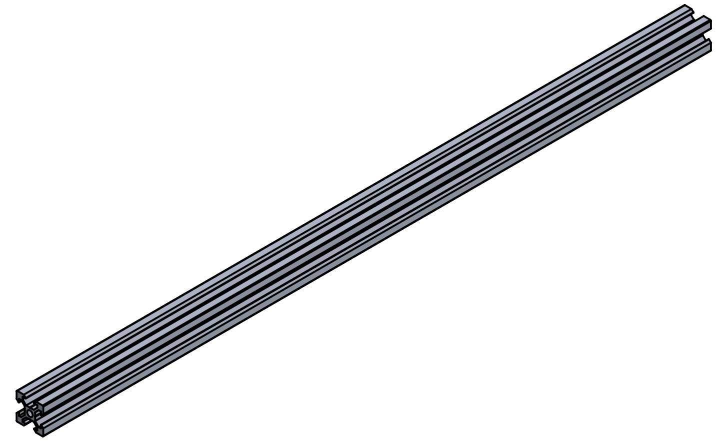
Cal Poly Mechanical Engineering SENIOR DESIGN	Material: SEE BOM		Title: POURING MECHANISM		Drwn. By: JULIA TRENKLE
	Dwg. #: B100	Nxt Asb: A100	Date: 2/8/2018	Scale: 1:5	Chkd. By: BRETT WITTMUSS



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL EDGES
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: CUSTOM L BRACKET	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B101	Nxt Asb: B100	Date:5/26/2018	Scale: 1:1	Chkd. By: BRETT WITTMUSS





Length	Part#
500	150-LP
1000	190-LP
1500	210-LP

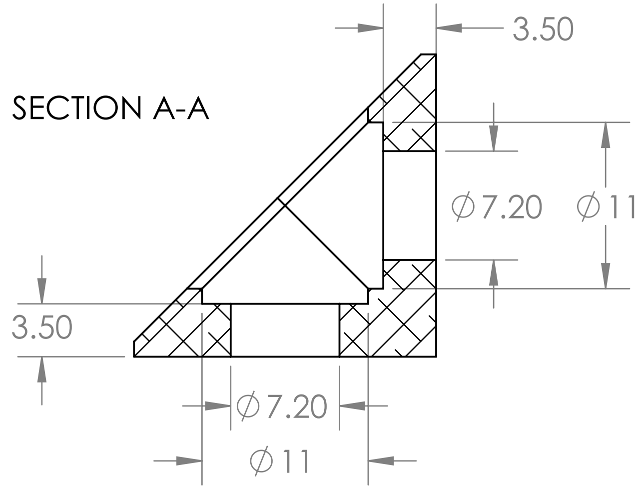
Wine Opener P/N: B102

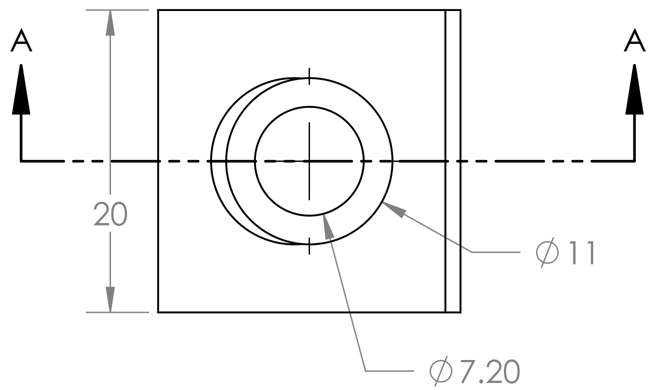
TITLE: V-Slot 20X20 Linear Rail

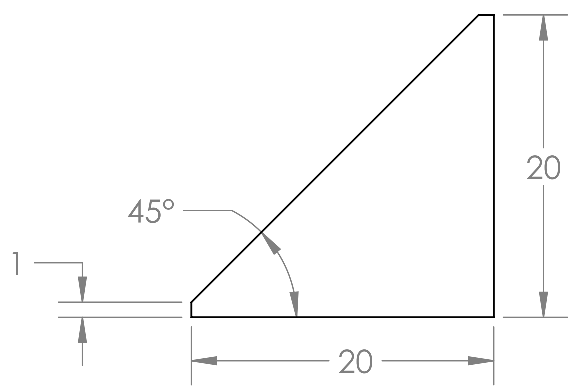
PART#

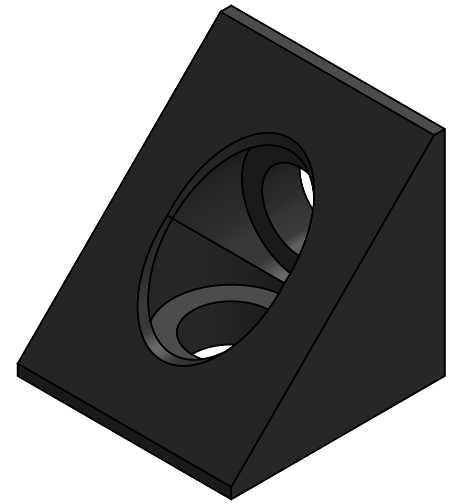
MATERIAL: Aluminum

OPENBUILDS





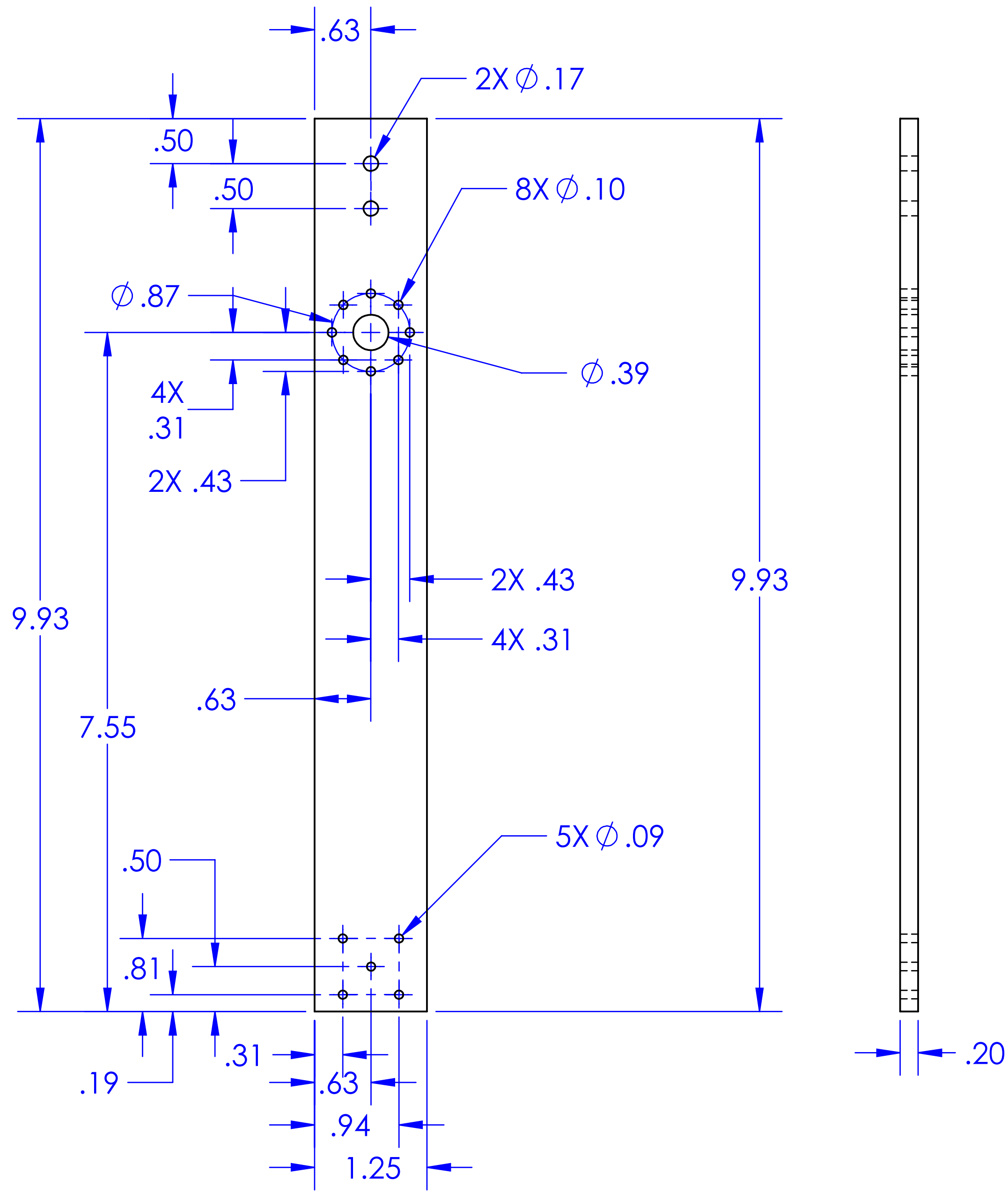


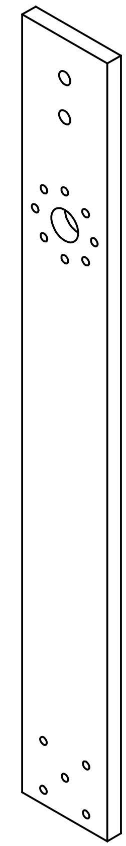


Wine Opener P/N: B103

TITLE:	Black Angle Corner Connector
PART# 540	MATERIAL: Aluminum

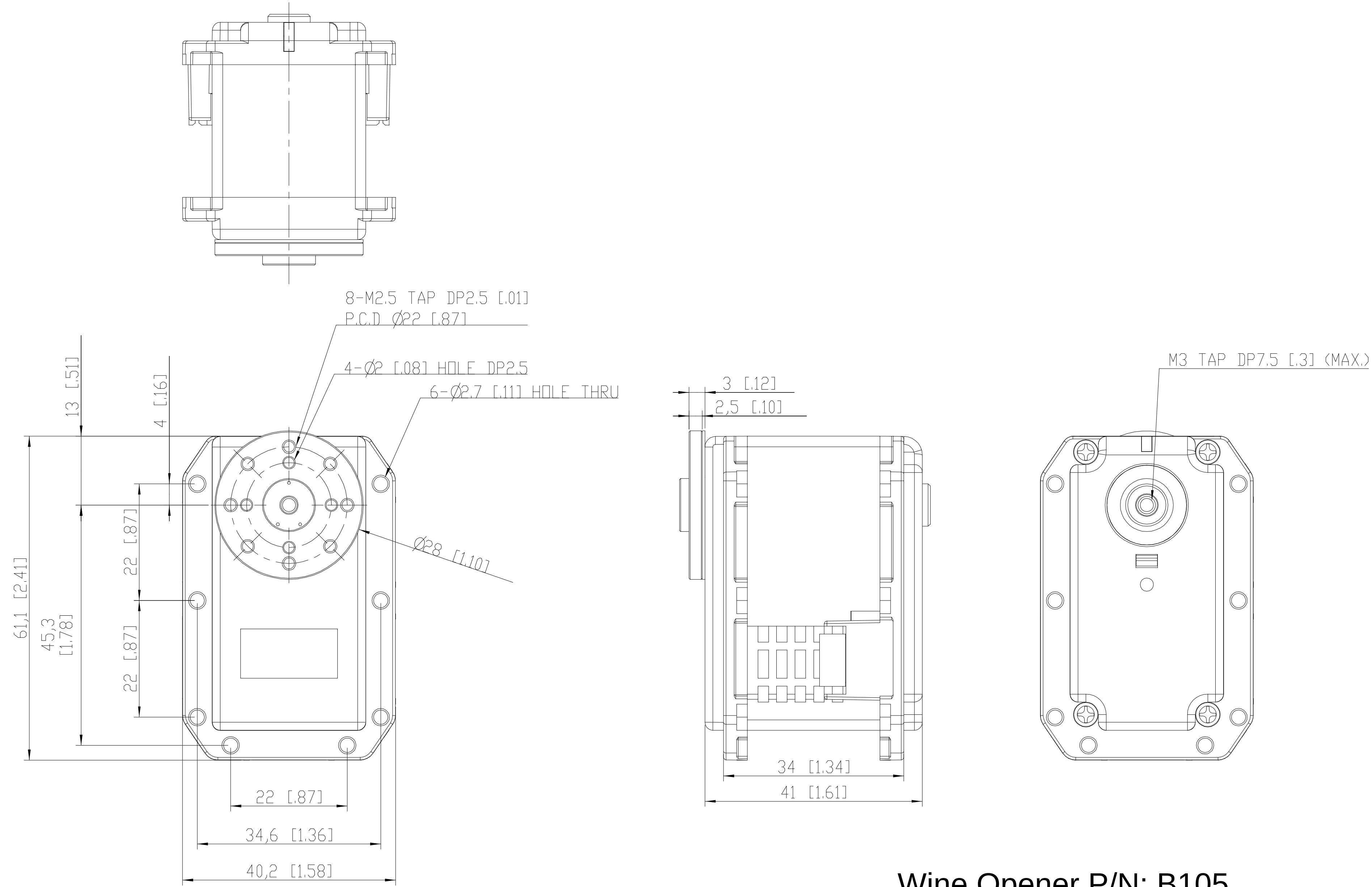
OPENBUILDS





NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL EDGES
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

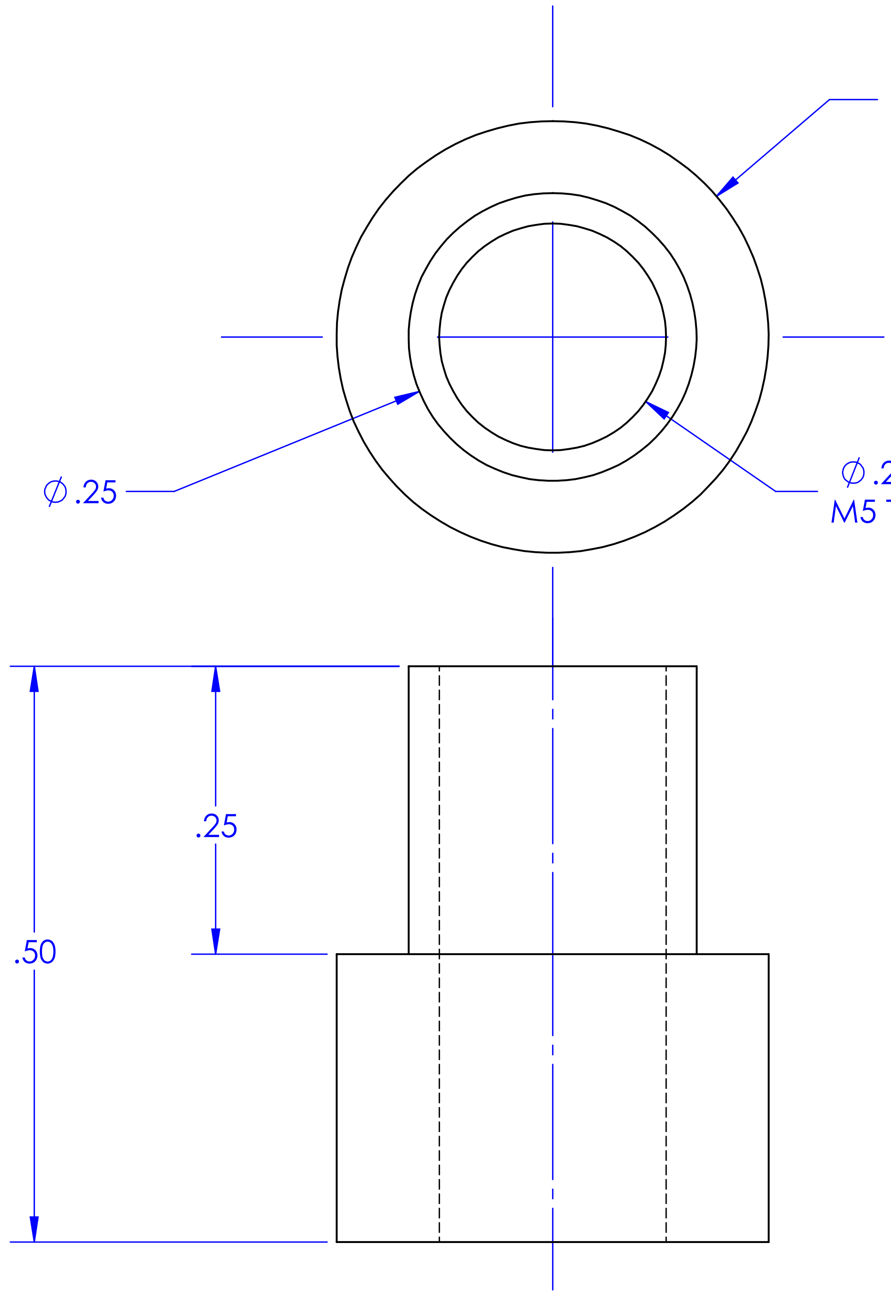
Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: GRIPPER BACKBONE		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B104	Nxt Asb: B100	Date:5/26/2018	Scale: 1:1	Chkd. By: BRETT WITTMUSS

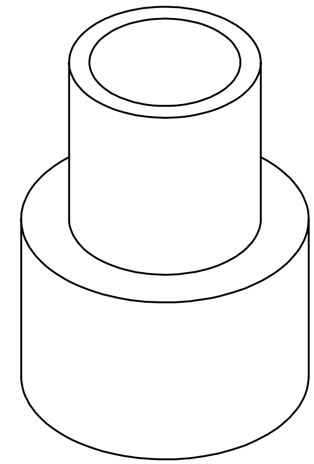


Wine Opener P/N: B105

[FOR REFERENCE ONLY]

Title		Material	Scale	Unit	Sheet	ROBOTIS
MX-64T						
	Date 04/26/2012		NONSCALE	mm	1 of 3	A4



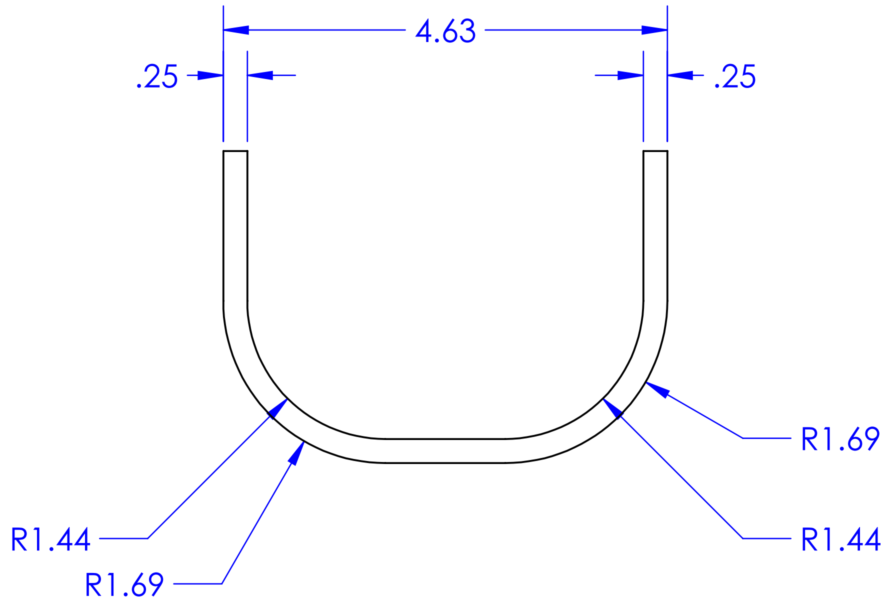


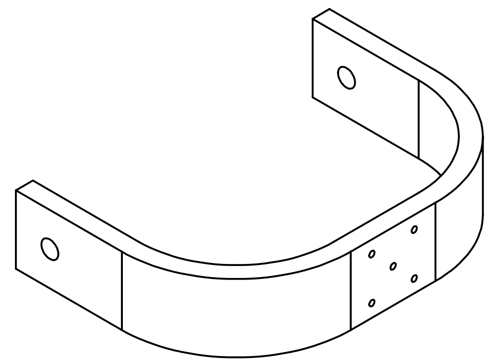
SCALE 4:1

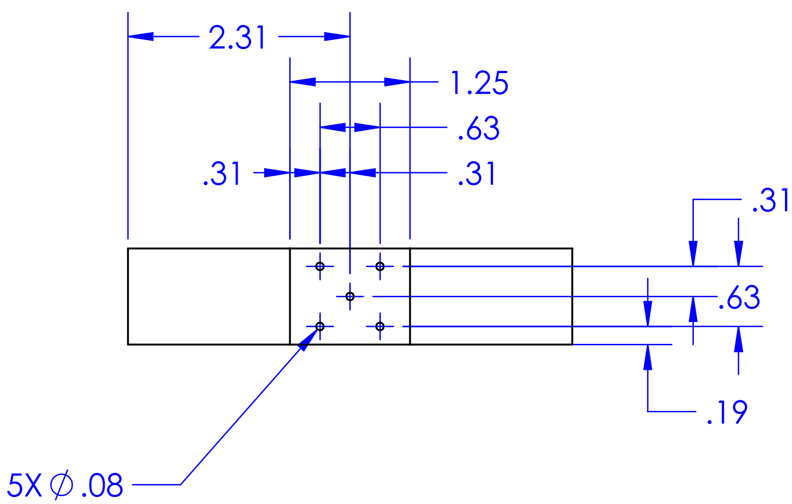
NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL EDGES
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

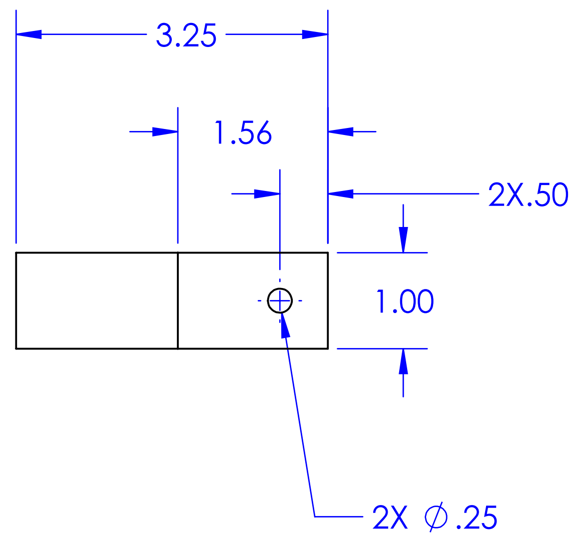
Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: CUSTOM SCREW INSERT		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B106	Nxt Asb: B100	Date:5/28/2018	Scale: 6:1	Chkd. By: BRETT WITTMUSS

NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.
BREAK ALL CORNERS

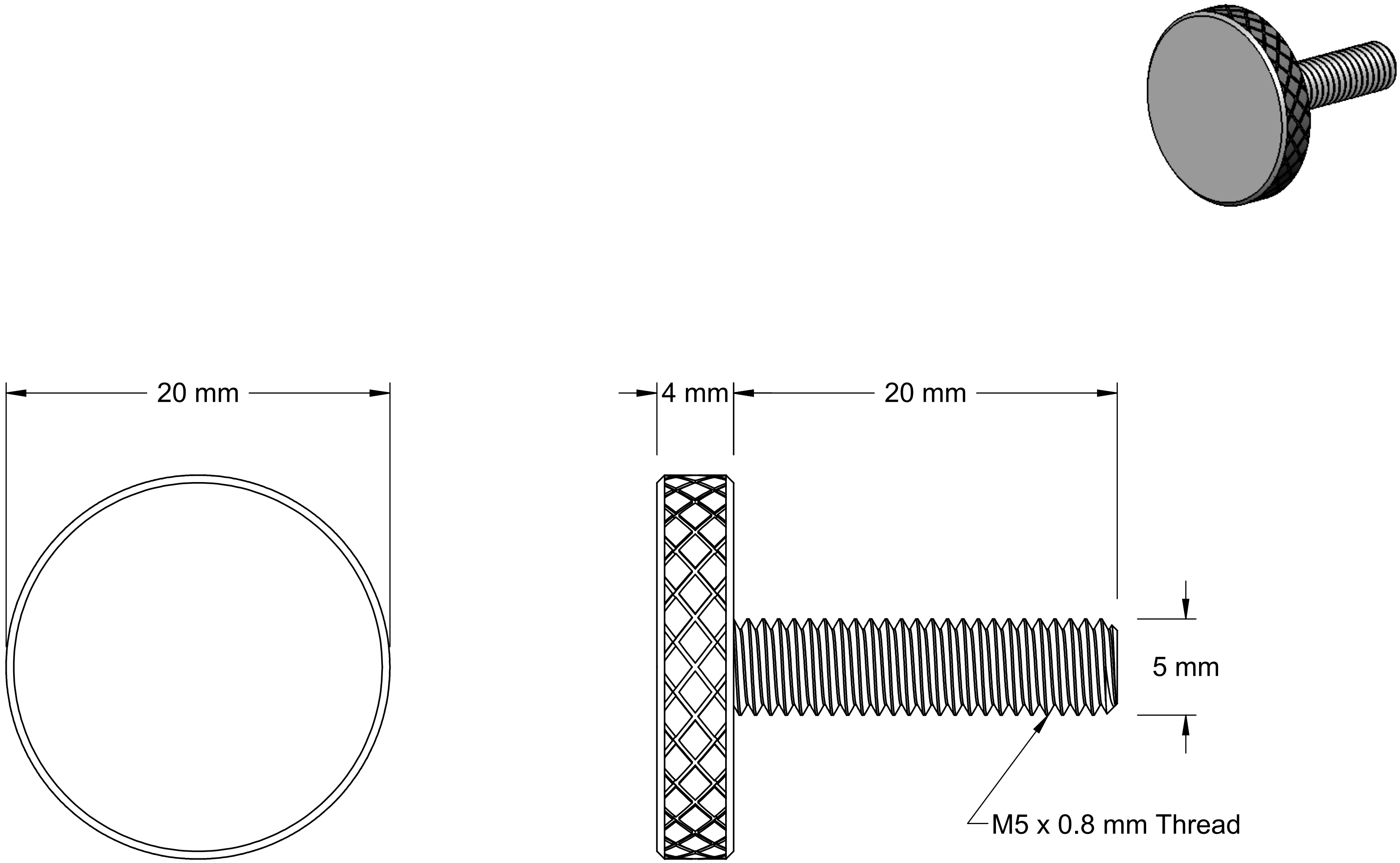






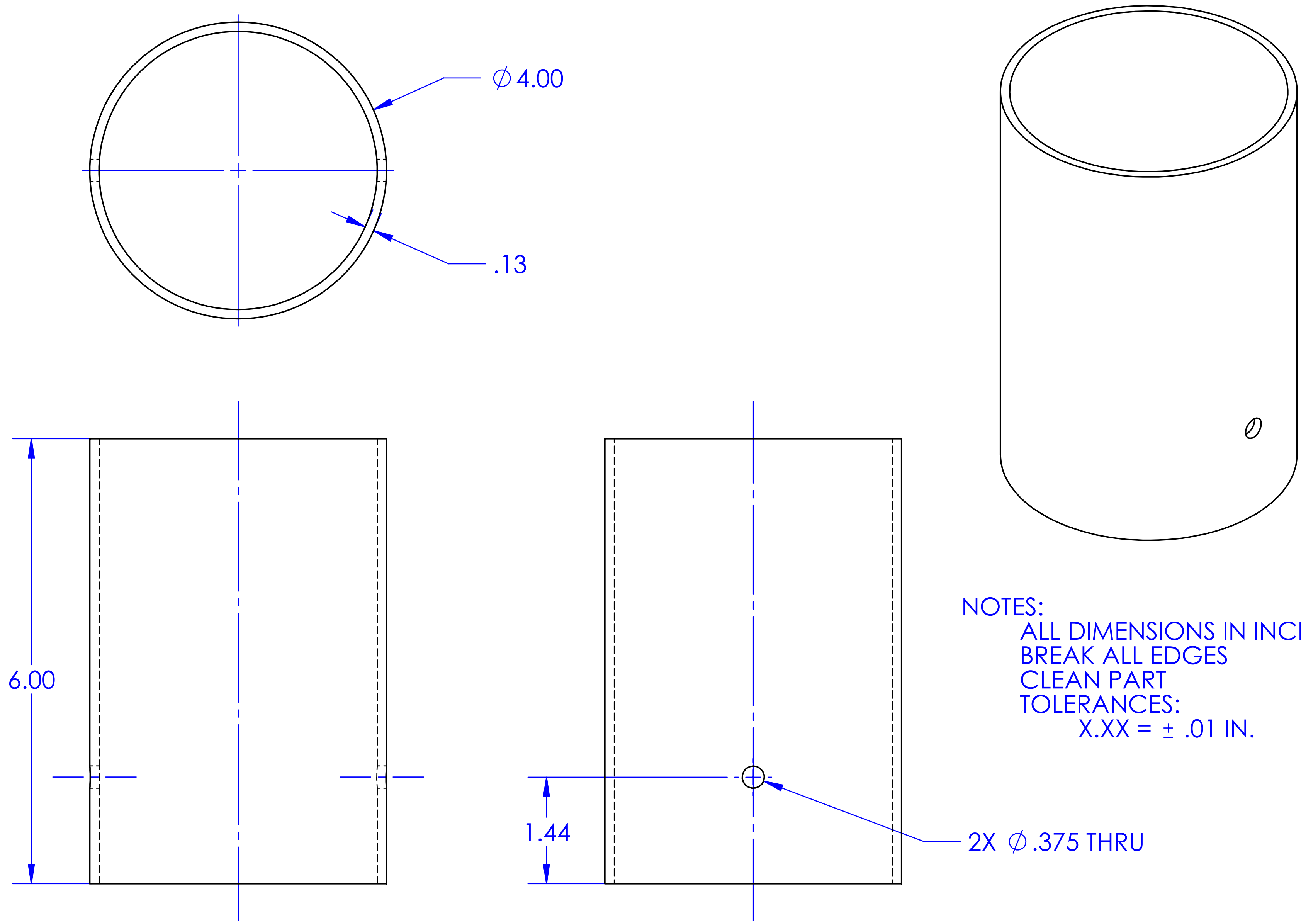


Cal Poly Mechanical Engineering SENIOR PROJECT	Material: 6061 ALUMINUM	Title: BOTTLE SLEEVE HOLDER CURVE	Drwn. By: JULIA TRENKLE
	Dwg. #: B107 / Nxt Asb: B100	Date: 2/8/2018 / Scale: 1:2	Chkd. By: BRETT WITTMUSS



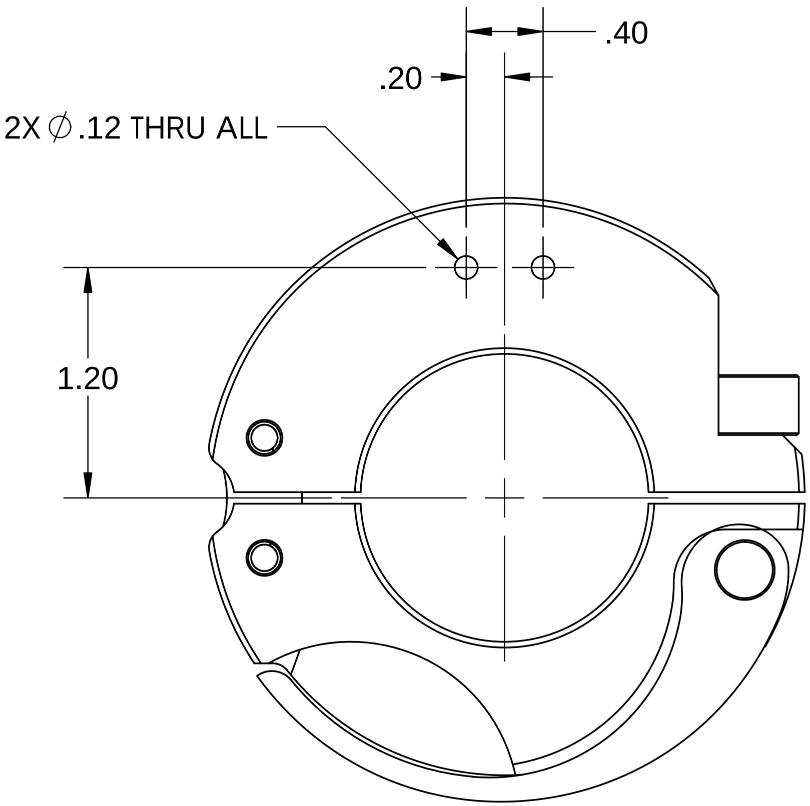
WINE OPENER P/N: B108

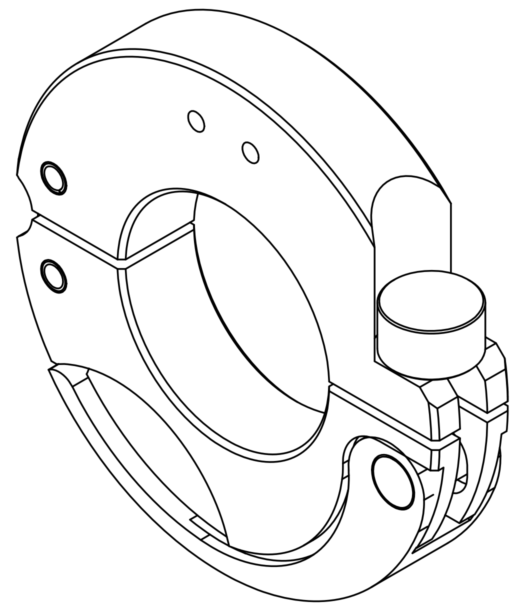
McMASTER-CARR® CAD	PART NUMBER 92552A447
http://www.mcmaster.com © 2013 McMaster-Carr Supply Company	Knurled Head Thumb Screw
Information in this drawing is provided for reference only.	



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL EDGES
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ACRYLIC		Title: BOTTLE SLEEVE		Drwn. By: BERKELEY DAVIS
	Dwg. #: B109	Nxt Asb: B100	Date:5/30/2018	Scale: 1:2	Chkd. By: BRETT WITTMUSS

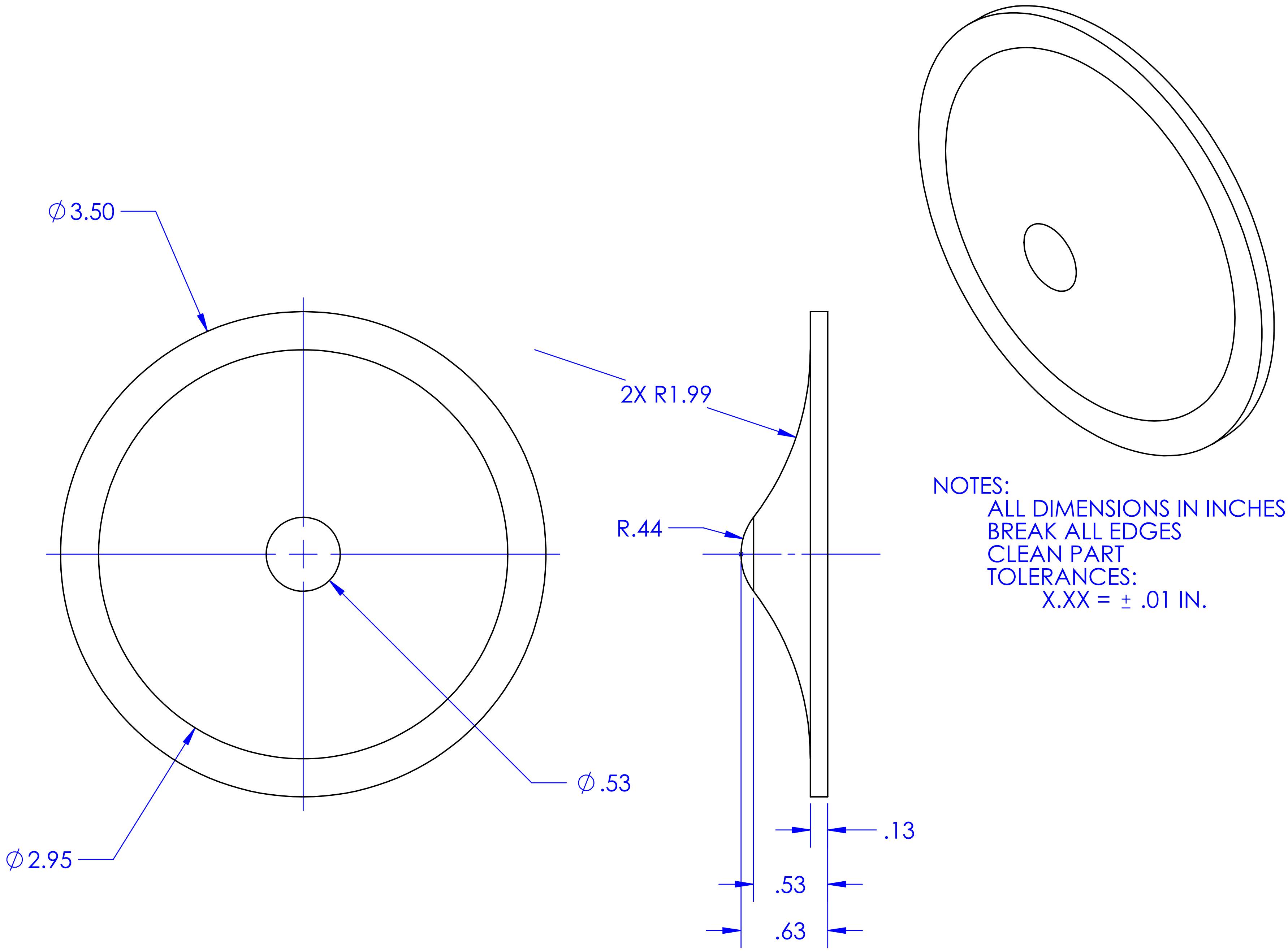




MODIFIED FROM 1-1/2" STAFF-LOK COLLAR HINGE TYPE
STAFFORD P/N: SLC2L108H

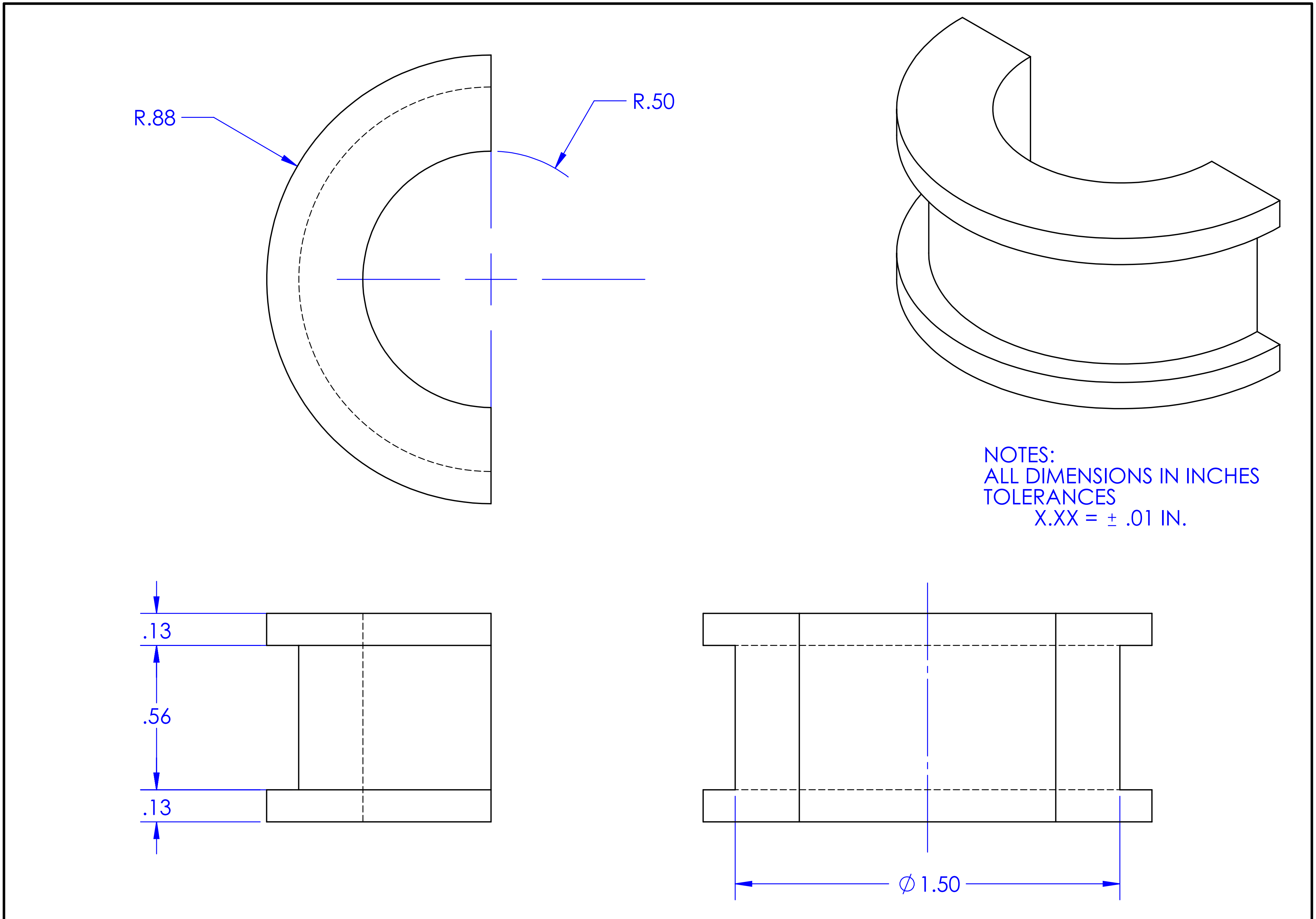
NOTES:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX = ± .005

Cal Poly Mechanical Engineering	Material: SEE CALLOUT		Title: NECK CLAMP	Drwn. By: JACOB RARDIN
SENIOR PROJECT	Dwg. #: B110	Nxt Asb: B100	Date: 2/9/2018 Scale: 1:1	Chkd. By: BRETT WITTMUSS



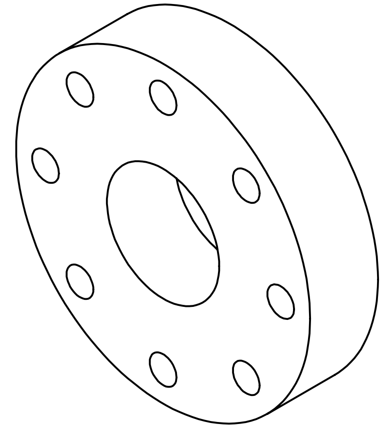
NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL EDGES
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

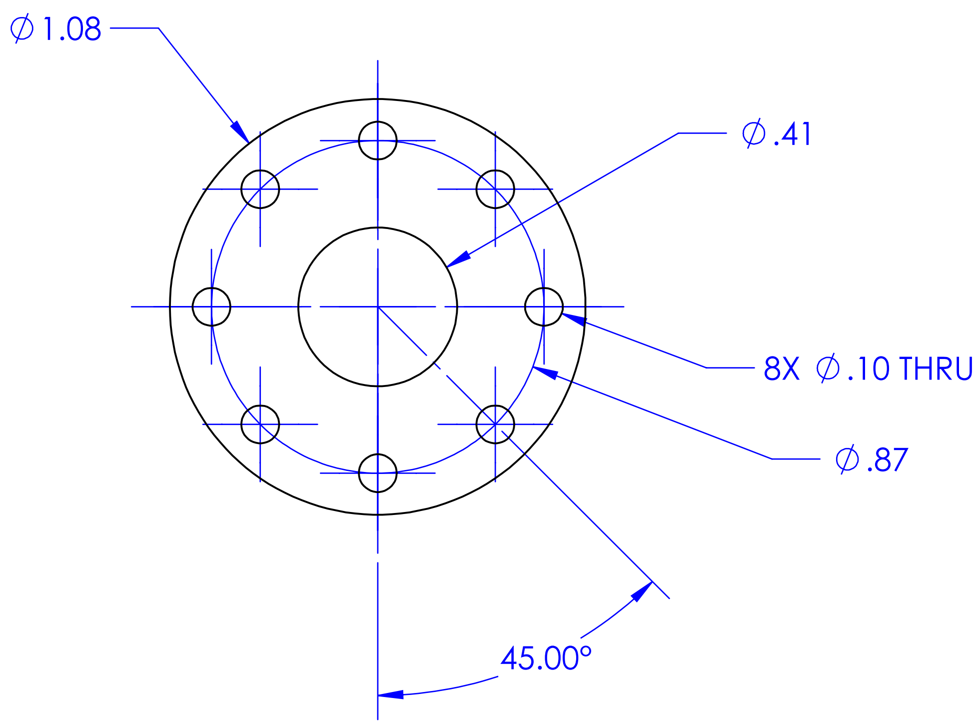
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: NYLON		Title: BOTTLE SLEEVE PUNT GRIP		Drwn. By: BERKELEY DAVIS
	Dwg. #: B111	Nxt Asb: B100	Date:5/30/2018	Scale: 1:1	Chkd. By: BRETT WITTMUSS

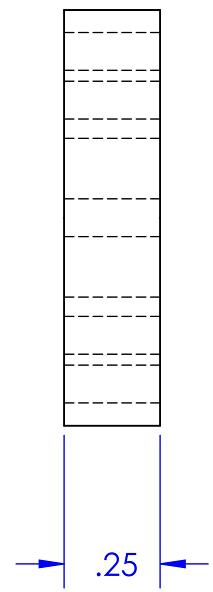


Cal Poly Mechanical Engineering	Material: RUBBER	Title: NECK CLAMP RUBBER INSERT	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B114 — Nxt Asb: B100	Date:5/27/2018 — Scale: 2:1	Chkd. By: BRETT WITTMUSS

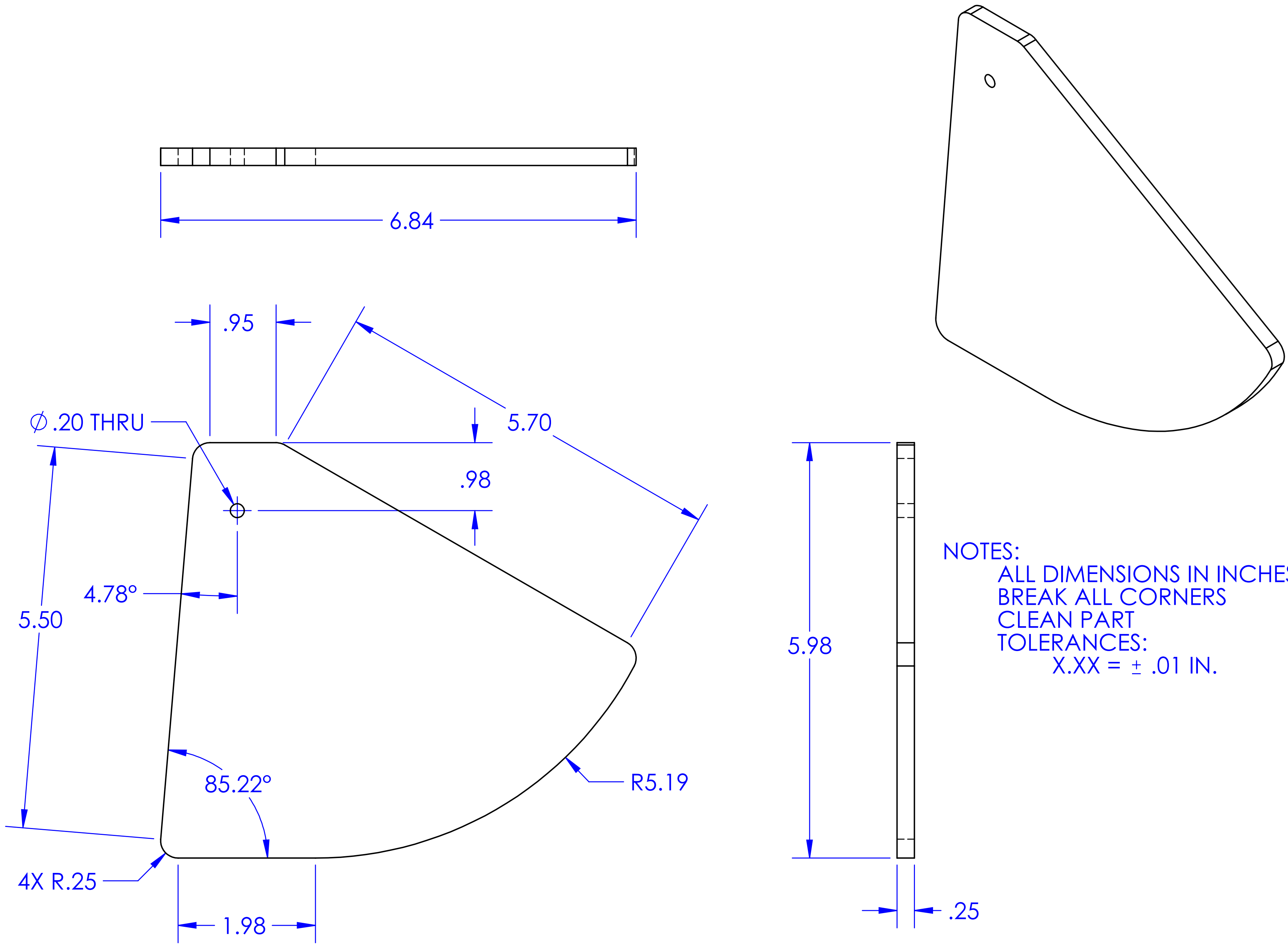
NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.





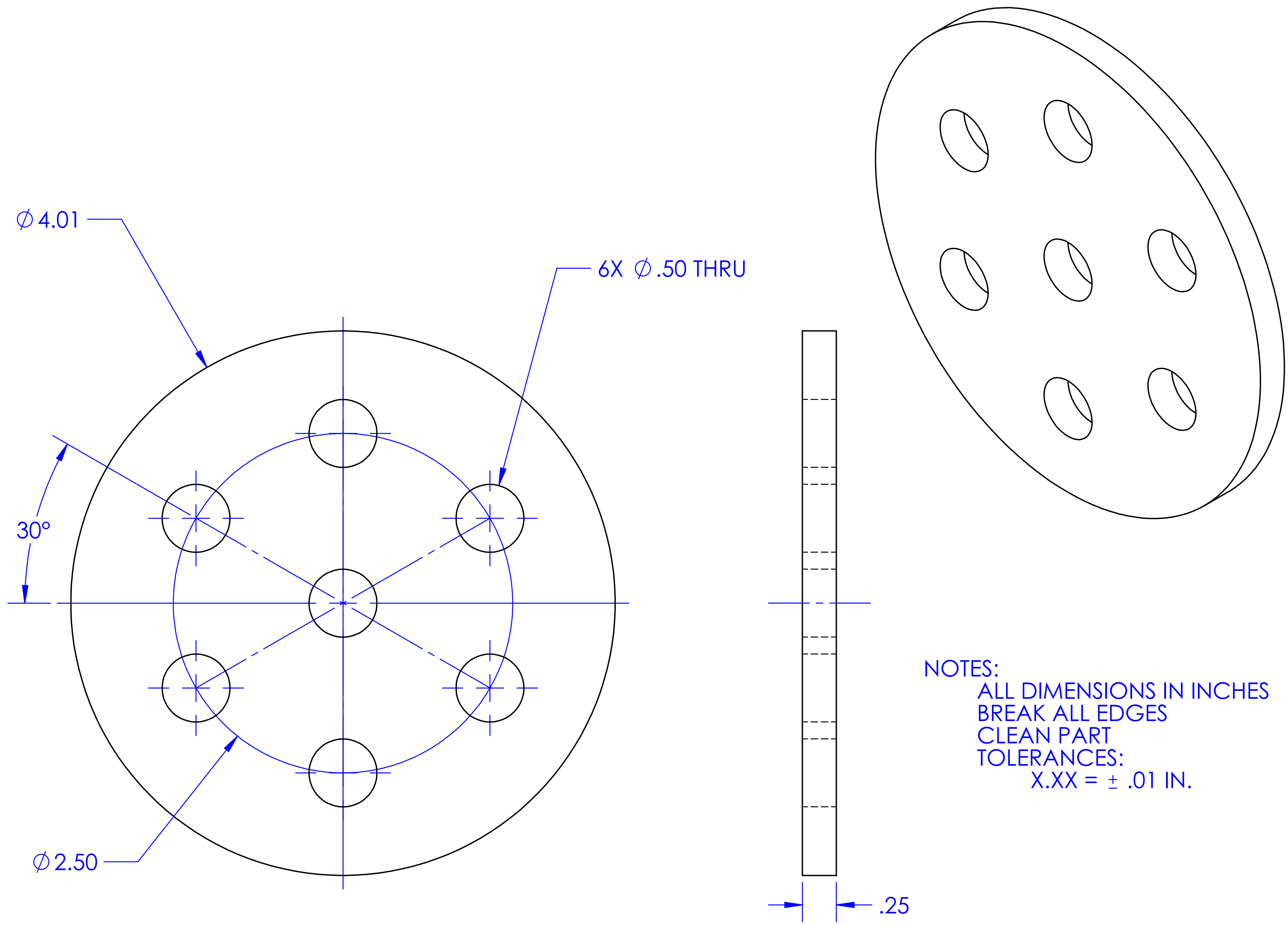


Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: POURING MOTOR SPACER	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B115	Nxt Asb: B100	Date:5/27/2018 / Scale: 2:1	Chkd. By: BRETT WITTMUSS



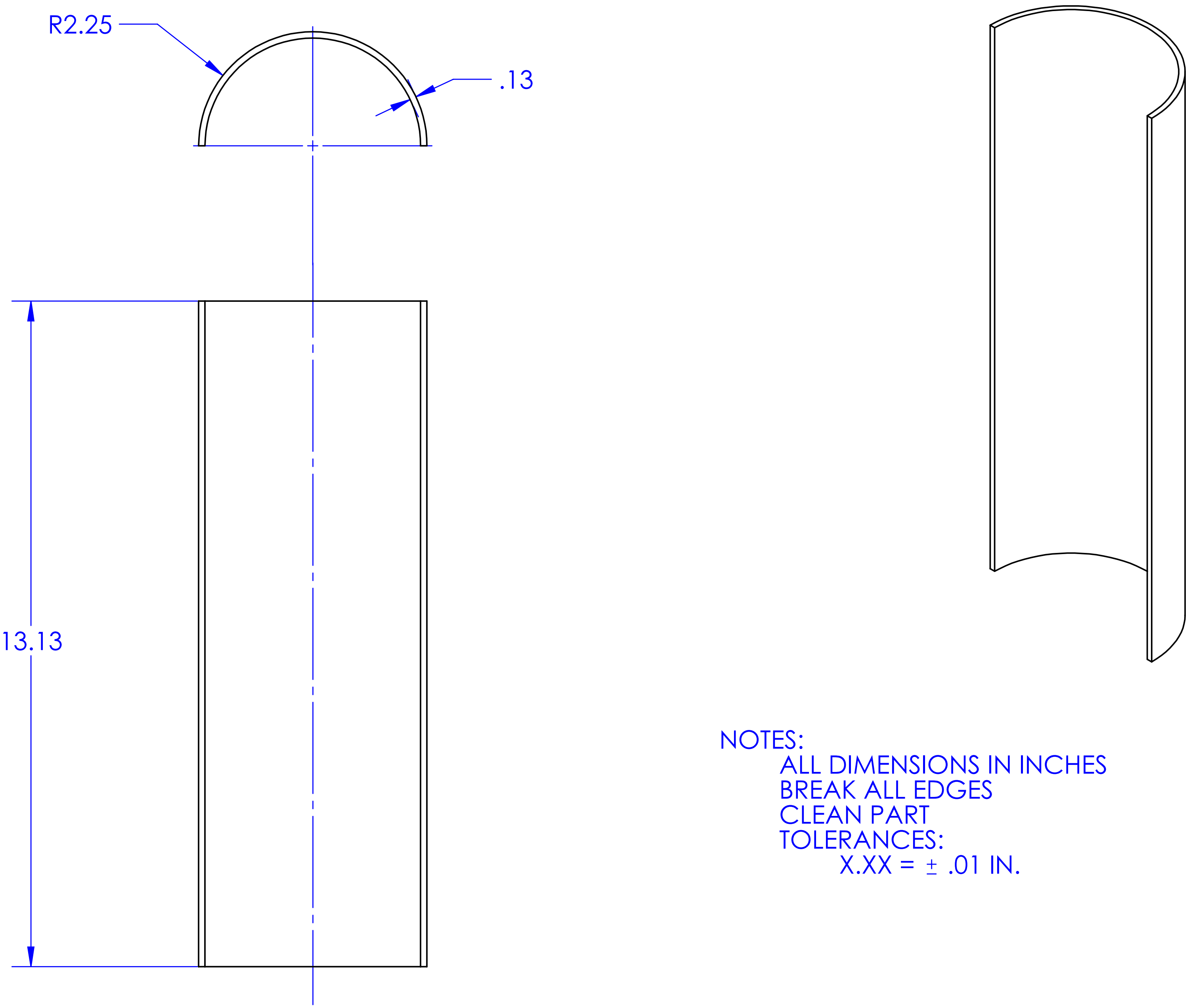
NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ACRYLIC		Title: FINGER SHIELD		Drwn. By: BERKELEY DAVIS
	Dwg. #: B116	Nxt Asb: B100	Date:5/28/2018	Scale: 1:2	Chkd. By: JULIA TRENKLE



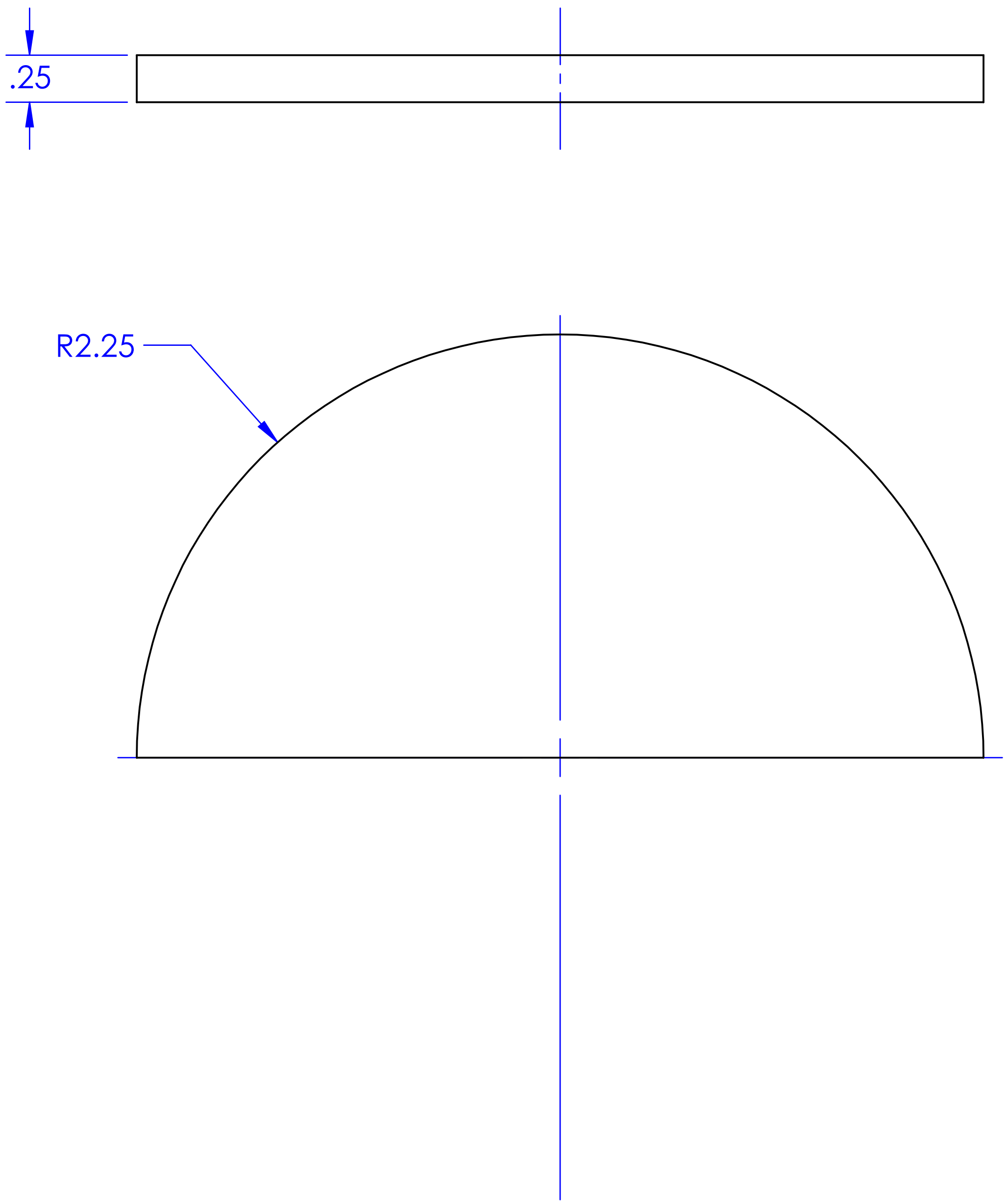
NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL EDGES
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

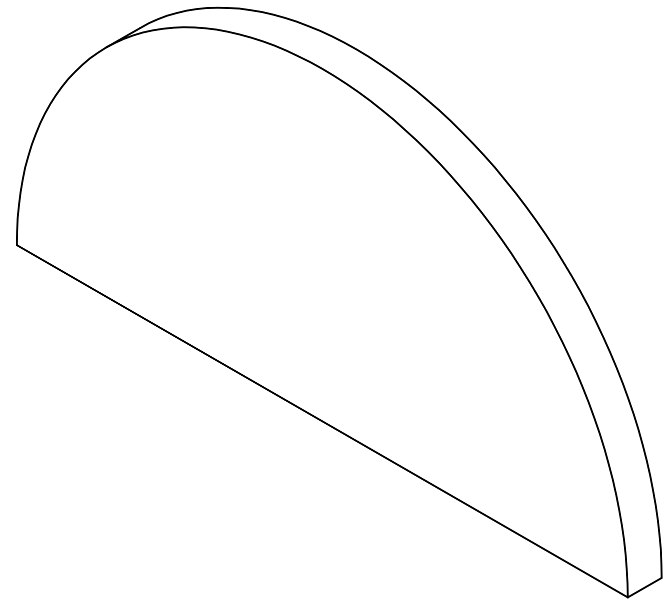
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ACRYLIC	Title: BOTTLE SLEEVE BASE	Drwn. By: BERKELEY DAVIS
	Dwg. #: B117 · Nxt Asb: B100	Date:5/29/2018 · Scale: 1:1	Chkd. By: BRETT WITTMUSS



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL EDGES
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

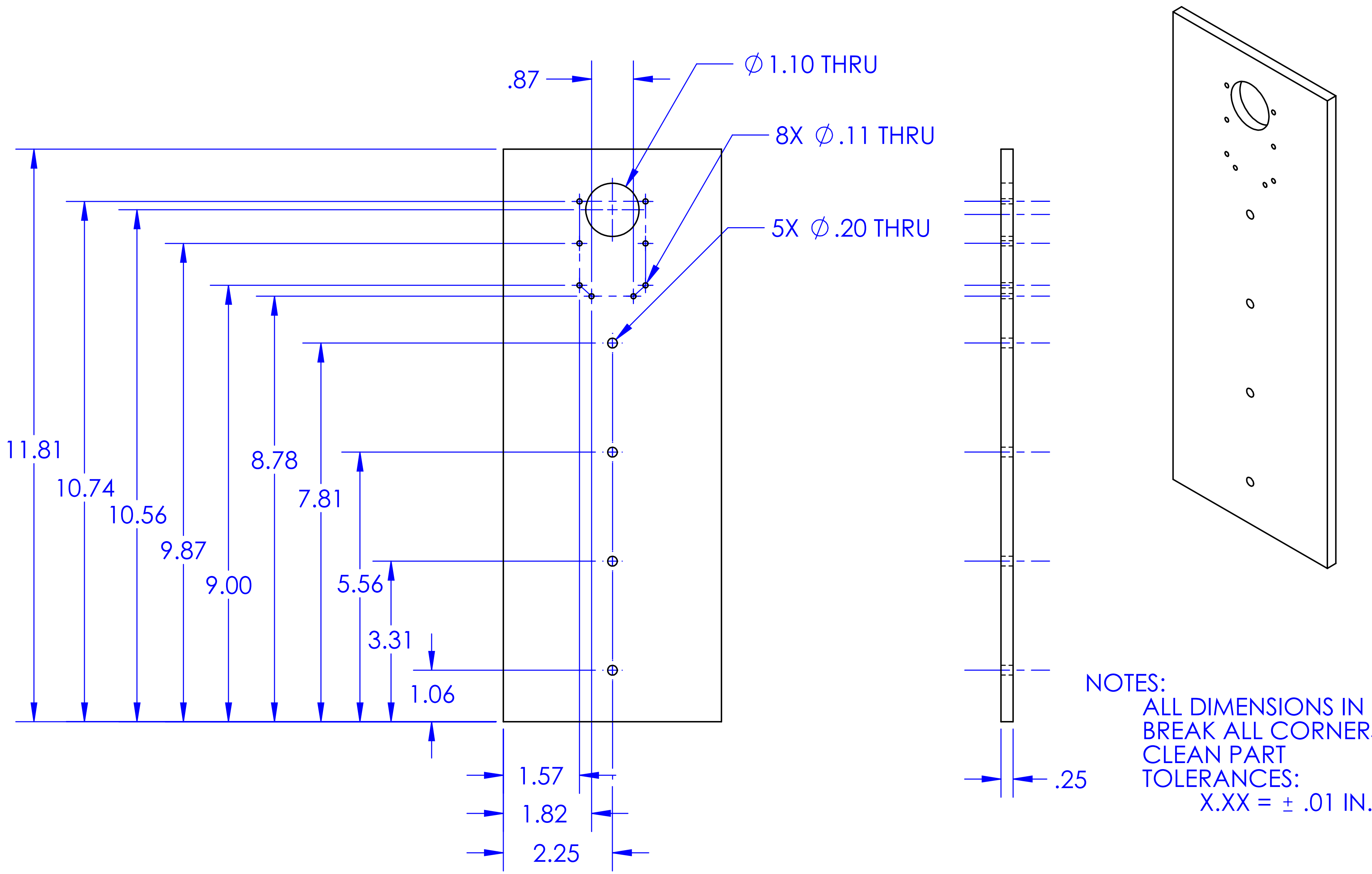
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ALUMINUM	Title: POURING HOUSING	Drwn. By: BERKELEY DAVIS
	Dwg. #: B118 / Nxt Asb: B100	Date:5/30/2018 / Scale: 1:3	Chkd. By: BRETT WITTMUSS





NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL EDGES
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: ALUMINUM		Title: POURING HOUSING CAP		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B119	Nxt Asb: B100	Date:5/30/2018	Scale: 1:1	Chkd. By: BRETT WITTMUSS



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

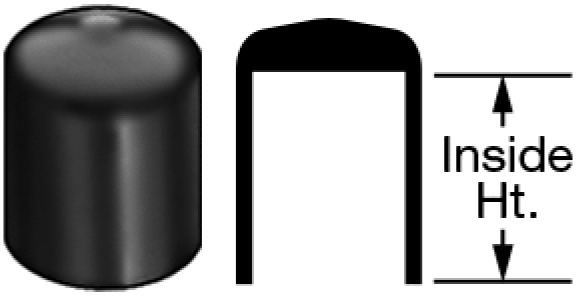
Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: POURING HOUSING COVER		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B120	Nxt Asb: B100	Date:5/29/2018	Scale: 1:3	Chkd. By: JULIA TRENKLE

McMASTER-CARR®

WINE OPENER P/N: B121

Flexible Vinyl Push-on Round Caps
for 3/16"-1/4" OD, 1/2" Inside Height

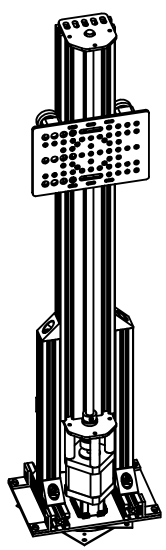
$3.89 per pack of 100
9753K12



Cap Type	Push On
For Shape	Round
For Surface Type	Unthreaded
Profile	Straight
Material	Vinyl Plastic
Flexibility	Flexible
For OD	3/16"-1/4"
Inside Height	1/2"
Hardness	Durometer 75A
Maximum Temperature	180° F
Color	Black
RoHS	Not Compliant

Slide these flexible caps on and they conform for a snug fit.

ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B201	PATTERN MOUNT PLATE TOP	ALUM.	1
2	B202	TURNTABLE BEARING	--	1
3	B203	AX-12A (TURNTABLE MOTOR)	--	1
4	B103	BLACK ANGLE CORNER CONNECTOR	--	6
5	B204	L BRACKET SINGLE	--	4
6	B205	2-HOLE CONNECTING BRACKET	ALUM.	2
7	B206	LINEAR TOWER ASSEMBLY	--	1
8	B113	FASTENER COMBINATION	--	24

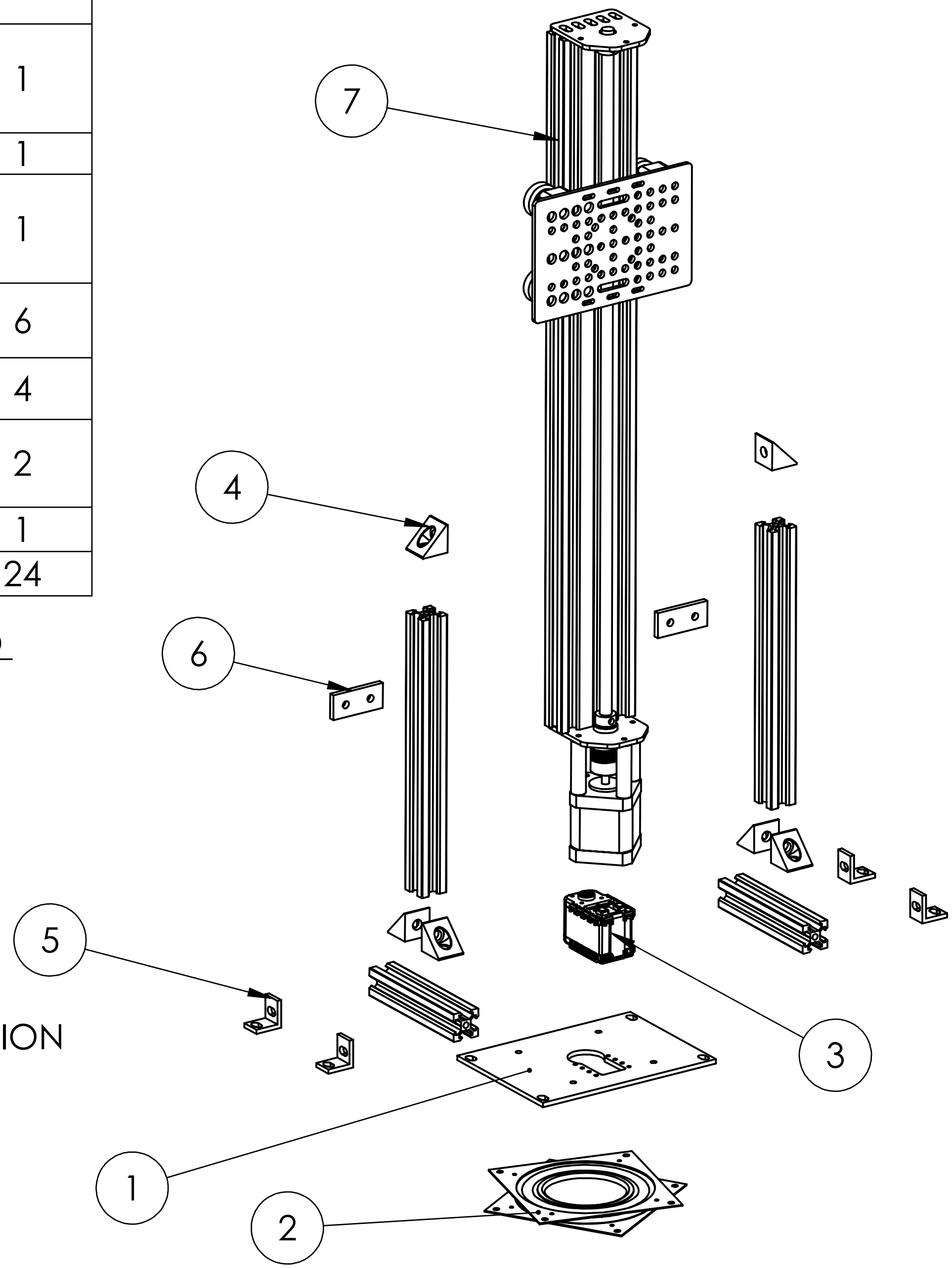


MANUFACTURED/ MODIFIED PARTS
B201
B205

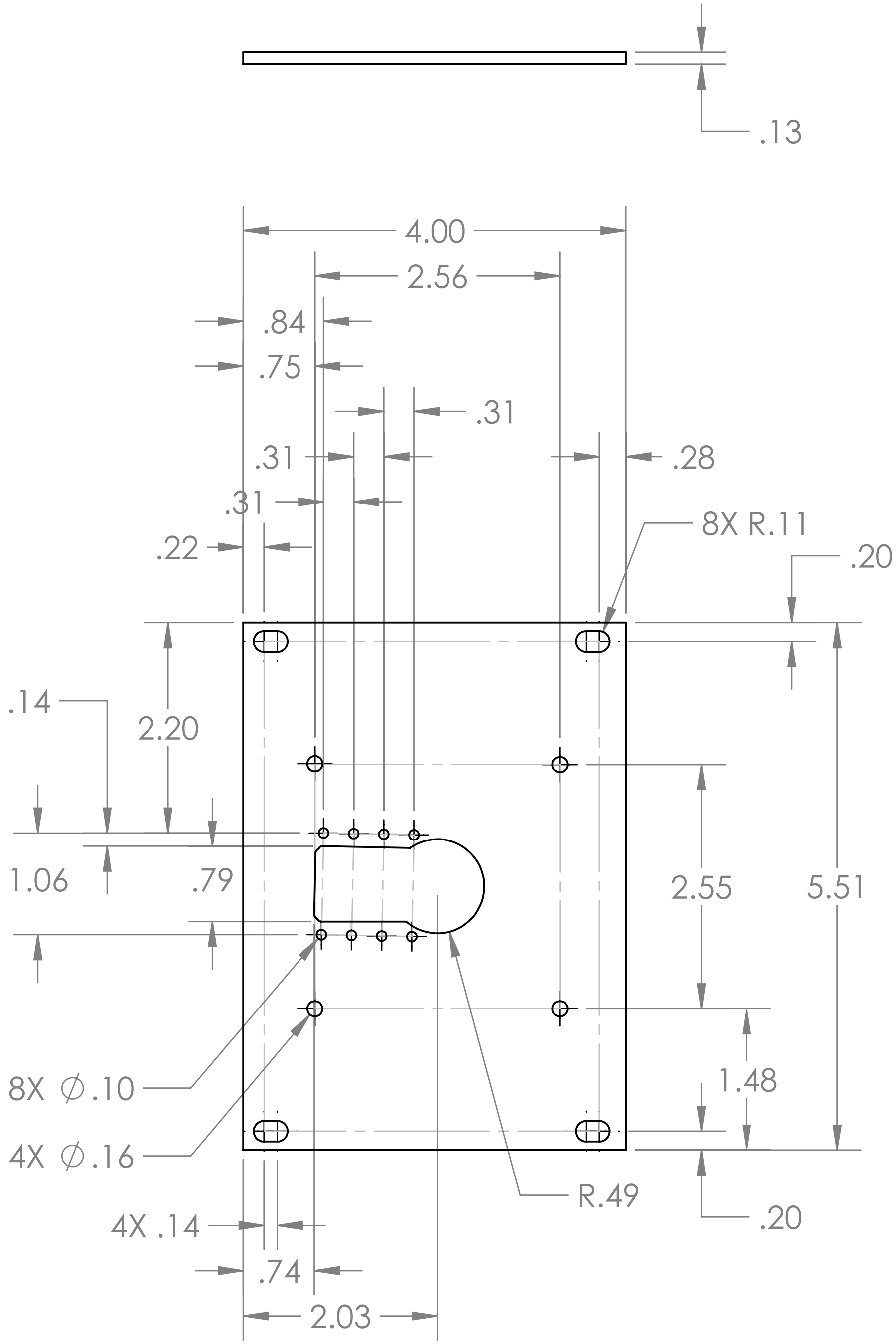
PURCHASED PARTS
B202
B203
B204
B206
B207
B208

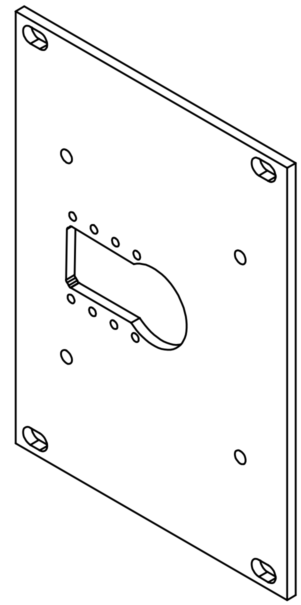
8

PARTS NOT SHOWN:
B103 FASTNER COMBINATION
-TEE NUT
- M5 8mm SCREW



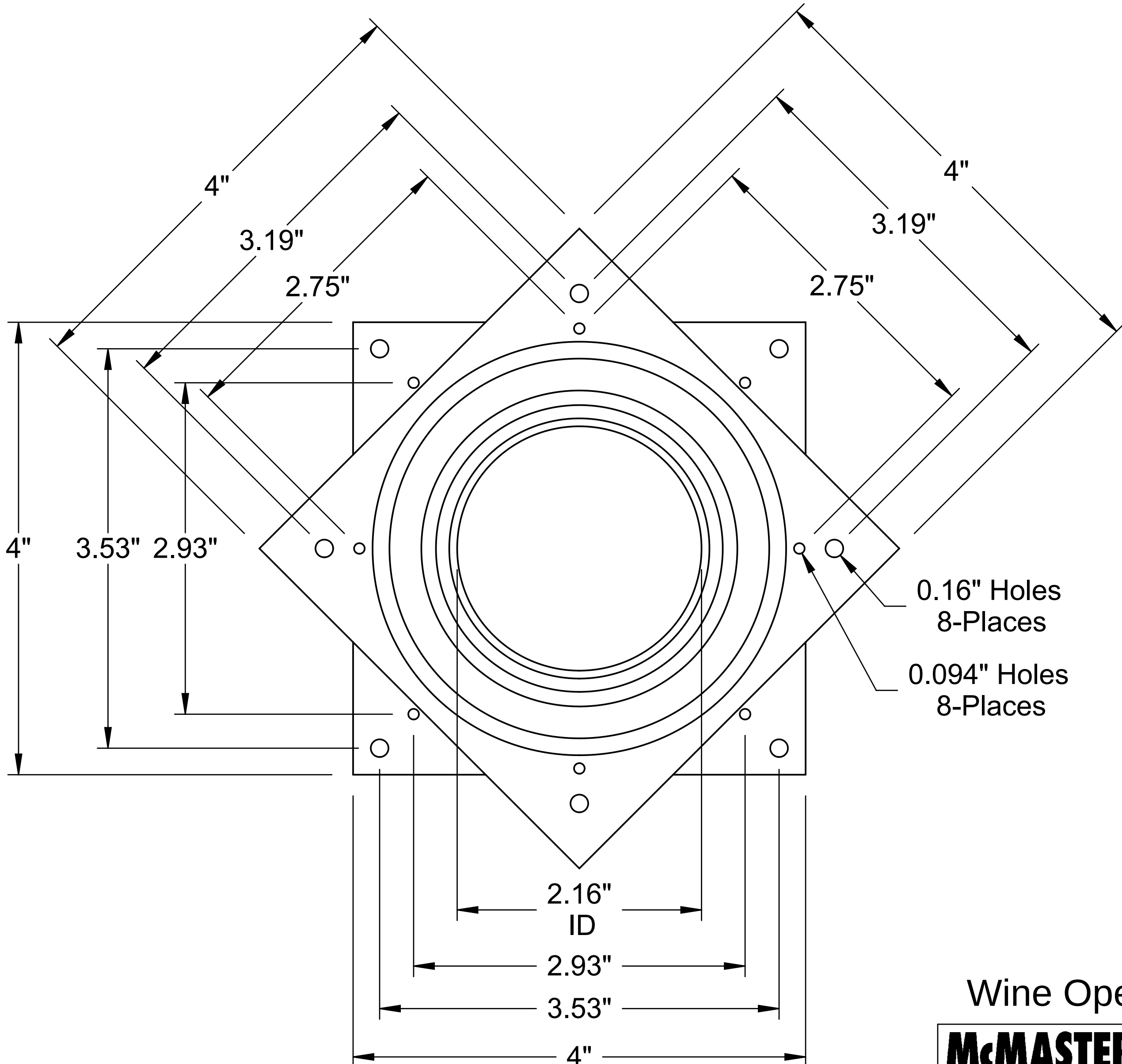
Cal Poly Mechanical Engineering SENIOR DESIGN	Material: SEE BOM		Title: TOWER		Drwn. By: JULIA TRENKLE
	Dwg. #: B200	Nxt Asb: A100	Date: 2/9/2018	Scale: 1:8	Chkd. By: BRETT WITTMUSS

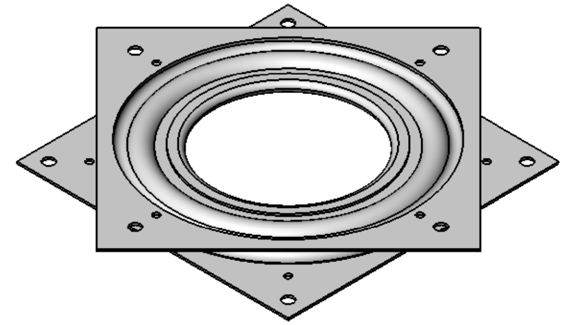


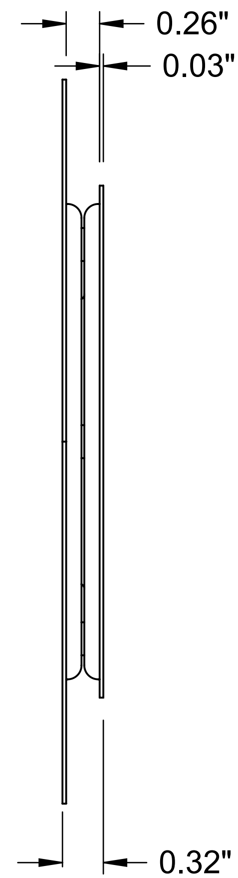


NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ±.01
BREAK ALL CORNERS

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: PATTERN MOUNT PLATE TOP	Drwn. By: BRETT WITTMUSS
SENIOR PROJECT	Dwg. #: B201	Nxt Asb: B200	Date: 2/9/2018 | Scale: 1:2	Chkd. By: JULIA TRENKLE

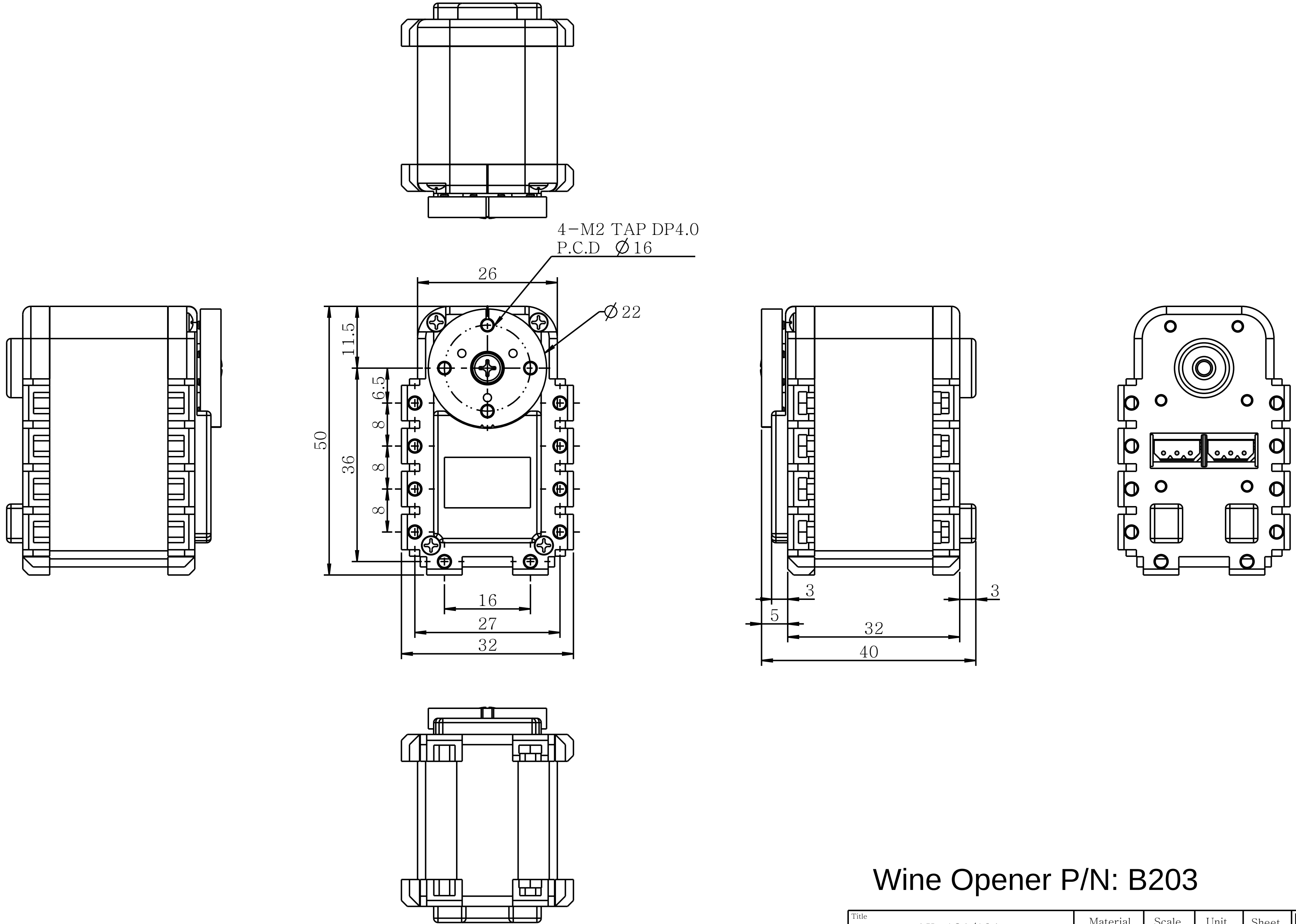






Wine Opener P/N: B202

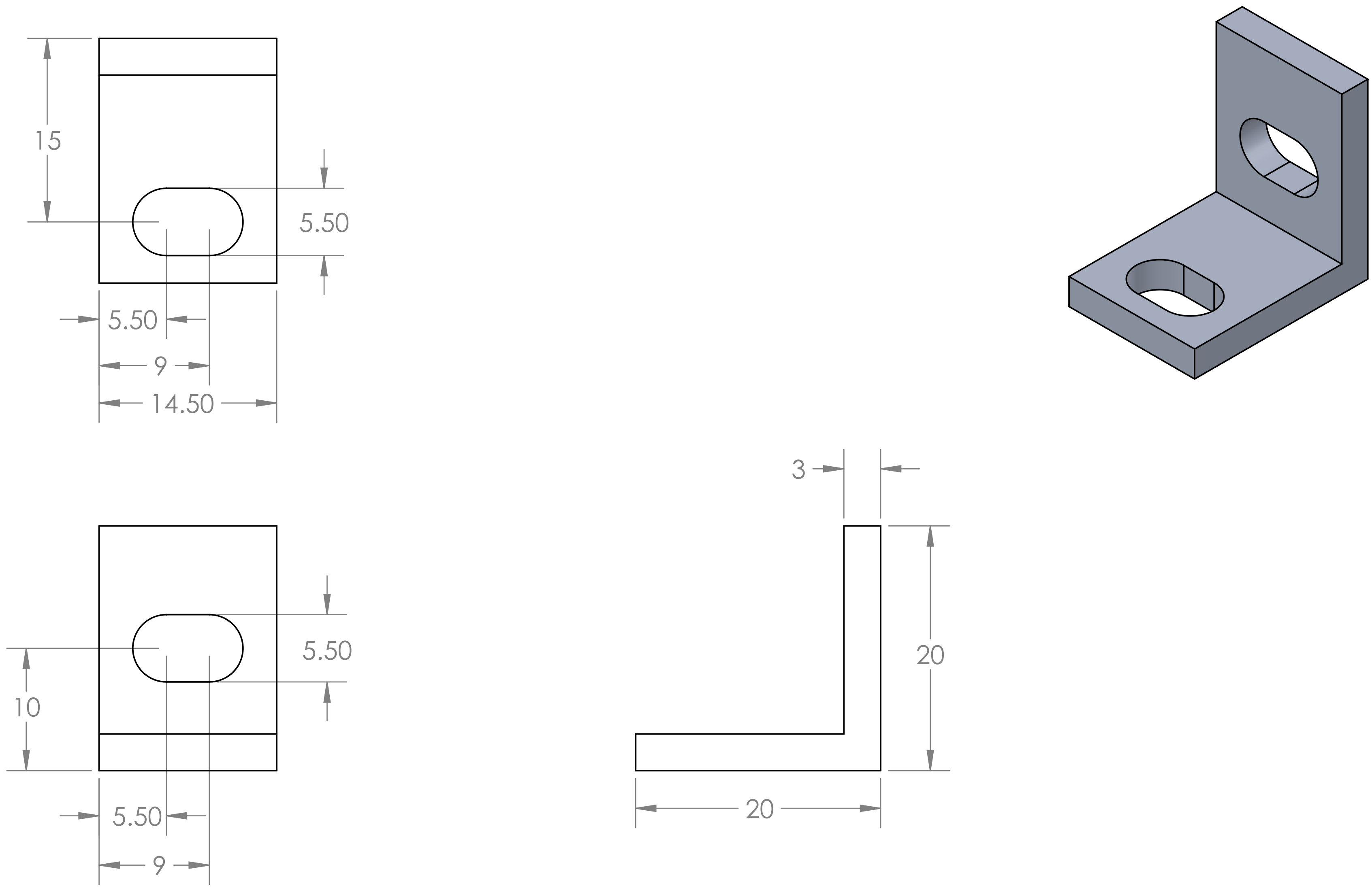
McMASTER-CARR® CAD	PART NUMBER	6031K17
http://www.mcmaster.com © 2011 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Galvanized Steel Turntable	



Wine Opener P/N: B203

Title	Material	Scale	Unit	Sheet	ROBOTIS
AX-12A/18A					
Date 01/24/2011		NONSCALE	mm	1 of 1	A4

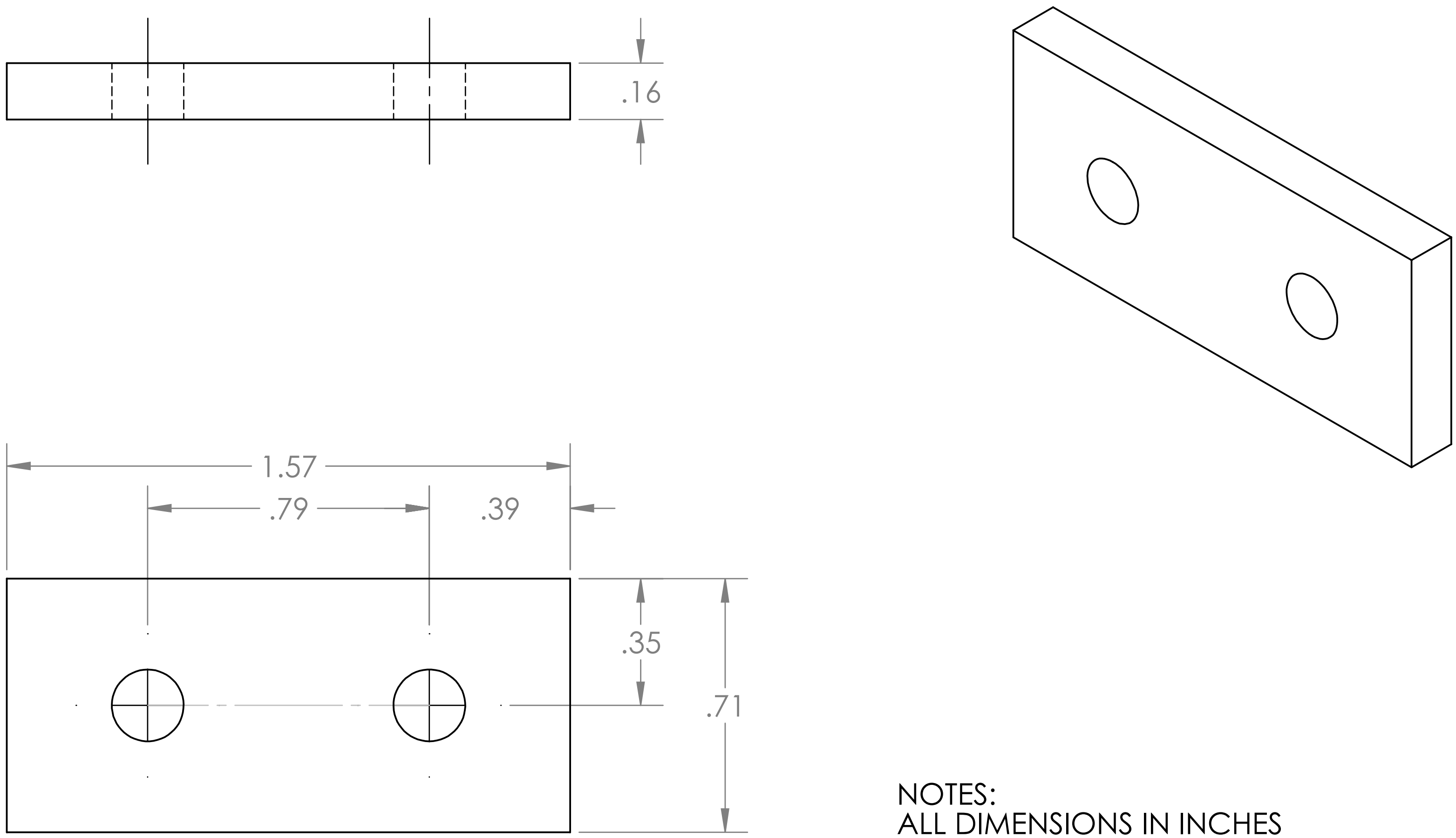
[FOR REFERENCE ONLY]



Wine Opener P/N: B204

TITLE: L Bracket Single	
PART# 545	MATERIAL: Aluminum

OPENBUILDS



NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ±.01
BREAK ALL CORNERS

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: 2 HOLE CONNECTING BRACKET	Drwn. By: BRETT WITTMUSS
SENIOR PROJECT	Dwg. #: B205	Nxt Asb: B200	Date: 2/9/2018	Scale: 2:1	Chkd. By: JULIA TRENKLE

Thanks to Rob Stehlik for his help and hard work in bringing this to the community!

Nema 23 leadscrew actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 199.1 (see note)
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	20.01	20.16	20.01	20.17	20.01	20.17	20.088	0.078	0.088
40	39.98	40.16	39.98	40.14	39.98	40.14	40.063	0.083	0.083
60	60.01	60.17	60.02	60.18	60.02	60.18	60.097	0.080	0.097
80	80	80.18	80	80.17	80.01	80.17	80.088	0.085	0.088
100	100.03	100.16	100.04	100.17	100.04	100.2	100.100	0.063	0.100
								Repeatability	**Accuracy**
								0.078	0.091

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Motor stalls at approximately 26lb (115N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 200 mm/s^2
Test done under no load
Max speed: 8000mm/min, beyond this motor stalls

Nema 23 high torque leadscrew actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 199.1 (see note)
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	19.98	20.17	19.98	20.17	19.98	20.17	20.075	0.095	0.095
40	40.01	40.18	40.01	40.18	40.01	40.18	40.095	0.085	0.095
60	60.04	60.23	60.04	60.22	60.03	60.22	60.130	0.093	0.130
80	80.07	80.2	80.07	80.2	80.07	80.2	80.135	0.065	0.135
100	100.06	100.23	100.06	100.23	100.05	100.2	100.142	0.085	0.142
								Repeatability	**Accuracy**
								0.085	0.119

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Motor stalls at approximately 66lb (294N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 200 mm/s^2
Test done under no load
Max speed: 5500mm/min, beyond this motor stalls

Nema 23 belt driven actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 26.667
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	19.8	20.95	19.86	20.98	19.86	21.03	20.413	0.573	0.573
40	40.05	40.99	40.04	41.03	40.06	41.06	40.538	0.488	0.538
60	60.16	61.13	60.15	61.17	60.16	61.2	60.662	0.505	0.662
80	79.98	80.91	79.96	80.94	79.96	80.97	80.453	0.487	0.487
100	100.1	100.94	100.2	100.97	100.2	101	100.553	0.413	0.553
								Repeatability	**Accuracy**
								0.493	0.563

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Belt skips at approximately 7.5lb (33N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 7000 mm/s^2
Test done under no load
Max speed: 75000mm/min, beyond this motor stalls

Nema 23 belt and pinion actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 26.667
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	19.76	21.11	19.78	21.12	19.79	21.12	20.447	0.670	0.670
40	39.86	41.18	39.85	41.19	39.87	41.19	40.523	0.663	0.663
60	59.99	61.29	59.98	61.28	60	61.28	60.637	0.647	0.647
80	79.74	81.1	79.76	81.09	79.76	81.09	80.423	0.670	0.670
100	99.85	101.18	99.85	101.16	99.82	101.2	100.505	0.665	0.665
								Repeatability	**Accuracy**
								0.663	0.663

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Belt skips at approximately 7.5lb (33N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 5000 mm/s^2
Test done under no load
Max speed: 60000mm/min, beyond this motor stalls

Nema 17 leadscrew actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 199.1 (see note)
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	19.95	20.11	19.95	20.12	19.95	20.1	20.030	0.080	0.080
40	39.96	40.1	39.98	40.1	39.97	40.1	40.035	0.065	0.065
60	59.98	60.14	59.98	60.14	59.98	60.12	60.057	0.077	0.077
80	79.97	80.14	79.98	80.13	79.98	80.13	80.055	0.078	0.078
100	99.97	100.12	99.96	100.12	99.96	100.1	100.038	0.075	0.075
								Repeatability	**Accuracy**
								0.075	0.075

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Motor stalls at approximately 13.5lb (60N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 200 mm/s^2
Test done under no load
Max speed: 11000mm/min, beyond this motor stalls

Nema 17 belt driven actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 26.667
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	20.04	20.51	20.06	20.52	20.06	20.51	20.283	0.230	0.283
40	39.85	40.31	39.86	40.32	39.87	40.31	40.087	0.227	0.227
60	59.96	60.44	59.98	60.43	59.99	60.42	60.203	0.227	0.227
80	80.03	80.54	80.06	80.53	80.07	80.53	80.293	0.240	0.293
100	99.83	100.39	99.84	100.37	99.85	100.4	100.108	0.268	0.268
								Repeatability	**Accuracy**
								0.238	0.260

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 2000mm/min
Acceleration set to 50 mm/s^2
Result: Motor stalls at approximately 2.5lb (11N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 200 mm/s^2
Test done under no load
Max speed: 20000mm/min, beyond this motor stalls

Nema 17 belt and pinion actuator

Positioning Test: move forward and back to five setpoints, repeated 6 times
Motor driver set to 8X microstepping, approximately 1.25A current
Steps/mm set to 40
Test done under no load

Target distance	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Average	Average Deviation	Actual Deviation
20	19.94	20.6	19.94	20.61	19.94	20.57	20.267	0.327	0.327
40	39.97	40.6	39.96	40.57	39.98	40.56	40.273	0.303	0.303
60	59.98	60.62	59.98	60.6	59.97	60.57	60.287	0.310	0.310
80	79.96	80.59	79.97	80.57	79.98	80.56	80.272	0.302	0.302
100	100	100.62	100	100.61	100	100.6	100.312	0.302	0.312
								Repeatability	**Accuracy**
								0.309	0.311

Force test: vary pressure in air cylinder until actuator can no longer move a set distance
Speed set to 4000mm/min
Acceleration set to 100 mm/s^2
Result: Motor stalls at approximately 2.5lb (11N)

Speed test: increase speed and acceleration and test long enough movement to allow actuator to reach full speed
distance tested was 250mm
Acceleration set to 4000 mm/s^2
Test done under no load
Max speed: 60000mm/min, beyond this motor stalls

WINE OPENER P/N: B207

OPENBUILDS

V-Slot Gantry Set - 20mm

(No reviews yet) Write a Review

SKU: 1196-Set

UPC: 819368021974

$38.99

WHEEL: REQUIRED

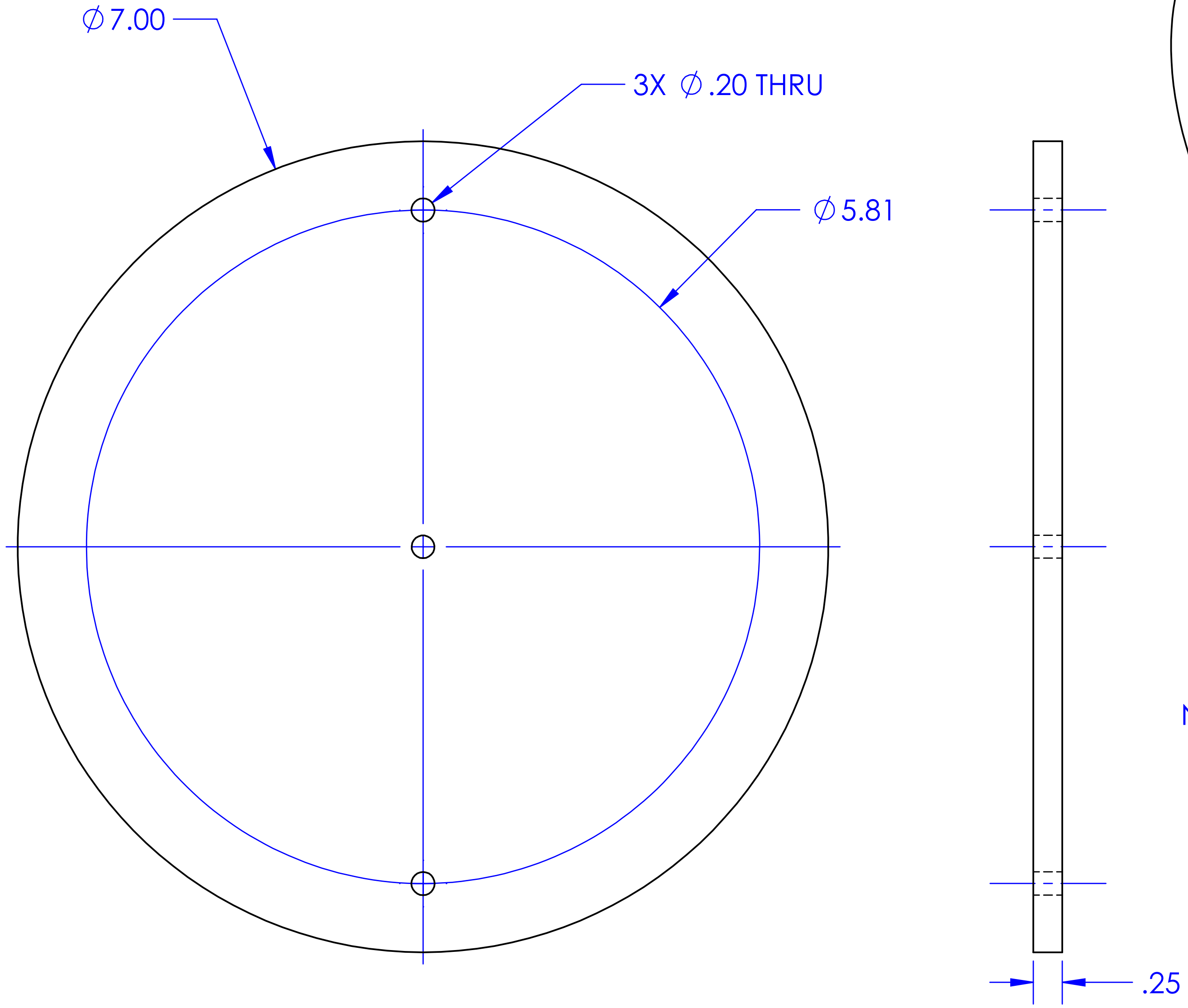
- Delrin Solid V Wheels
- Xtreme Solid V Wheels

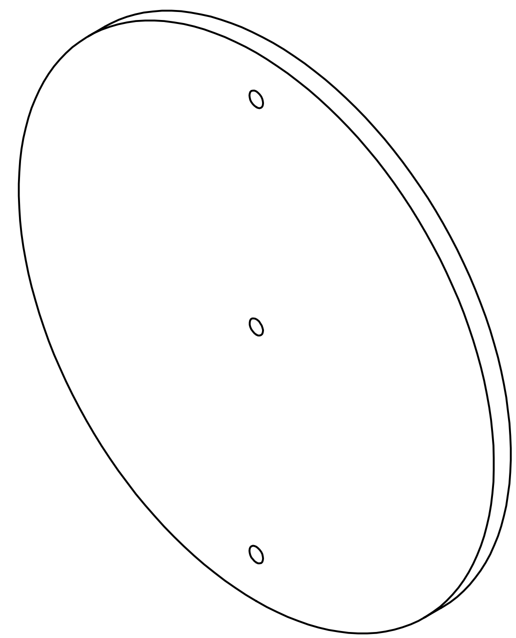
QUANTITY:

1

ADD TO CART

ADD TO WISH LIST

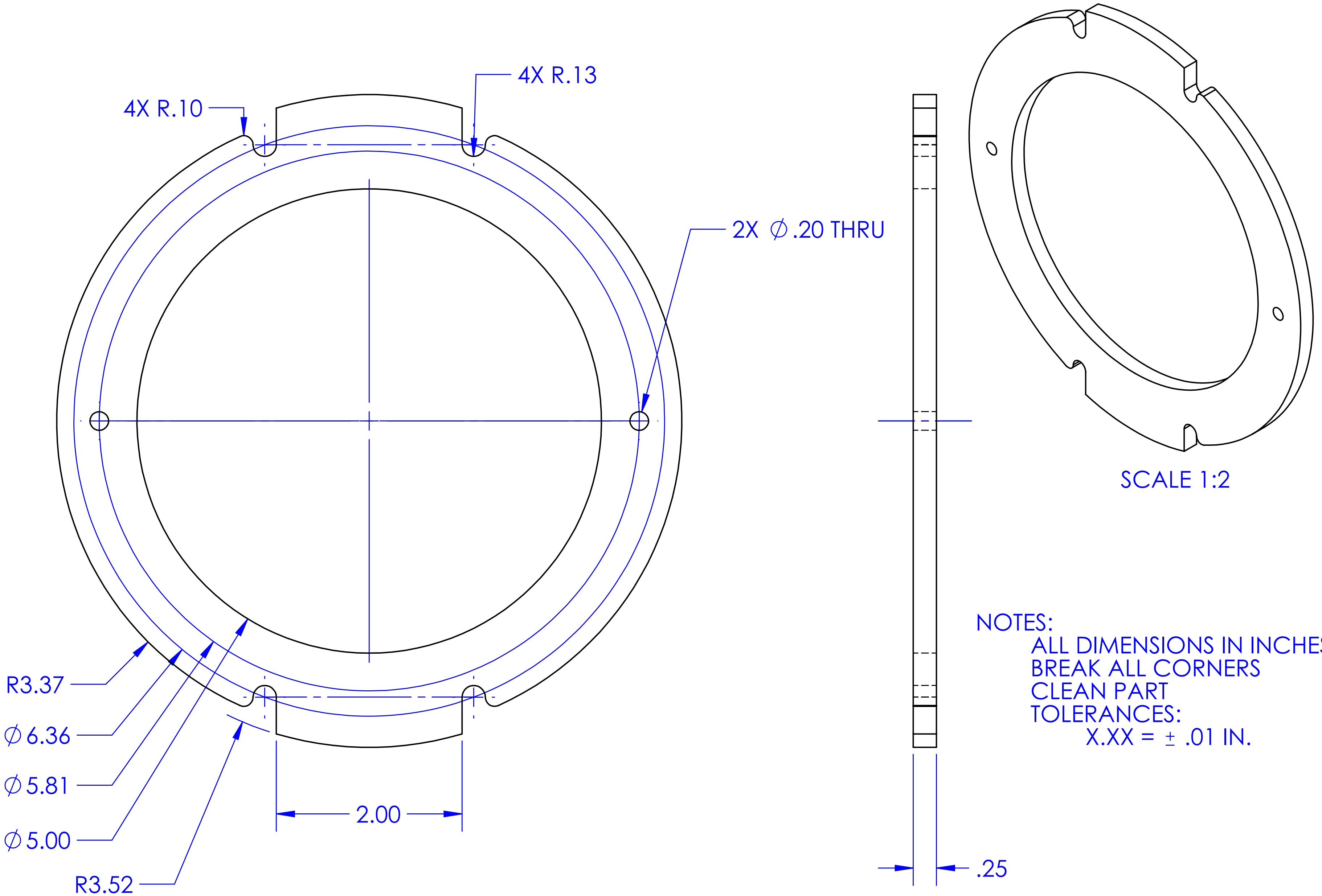




SCALE 1:2

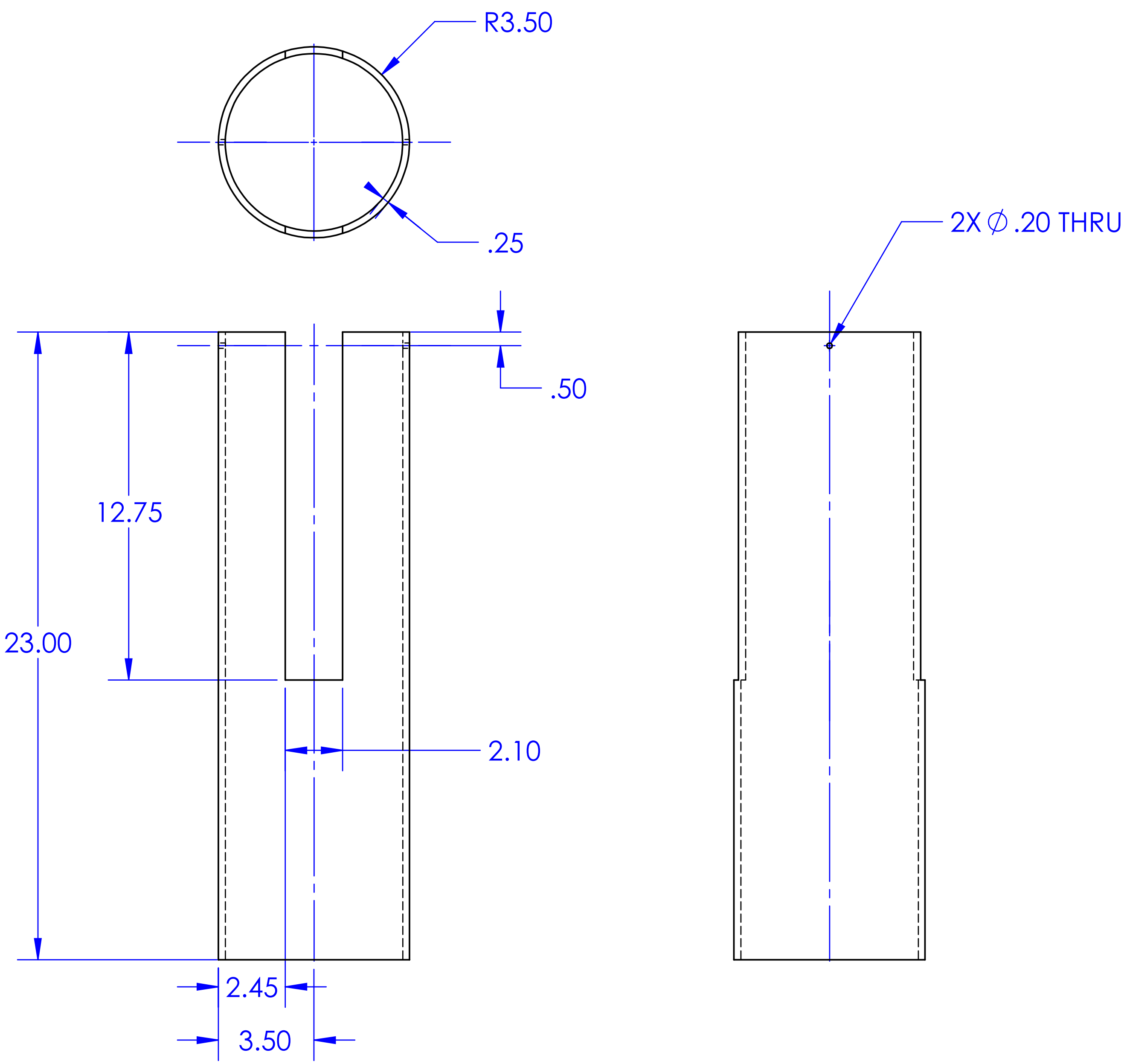
NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL CORNERS
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

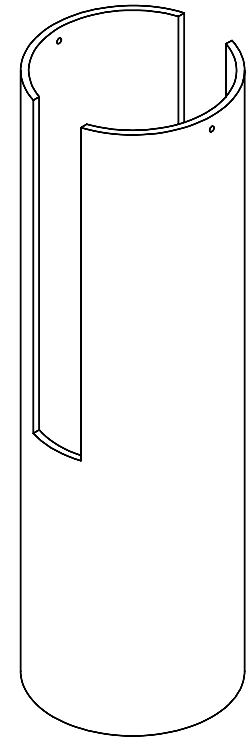
Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: TOWER HOUSING CAP	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B208	Nxt Asb: B200	Date:5/29/2018 — Scale: 2:3	Chkd. By: JULIA TRENKLE



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: 6061 ALUMINUM		Title: TOWER HOUSING RING		Drwn. By: BERKELEY DAVIS
	Dwg. #: B209	Nxt Asb: B200	Date:5/29/2018	Scale: 2:3	Chkd. By: JULIA TRENKLE

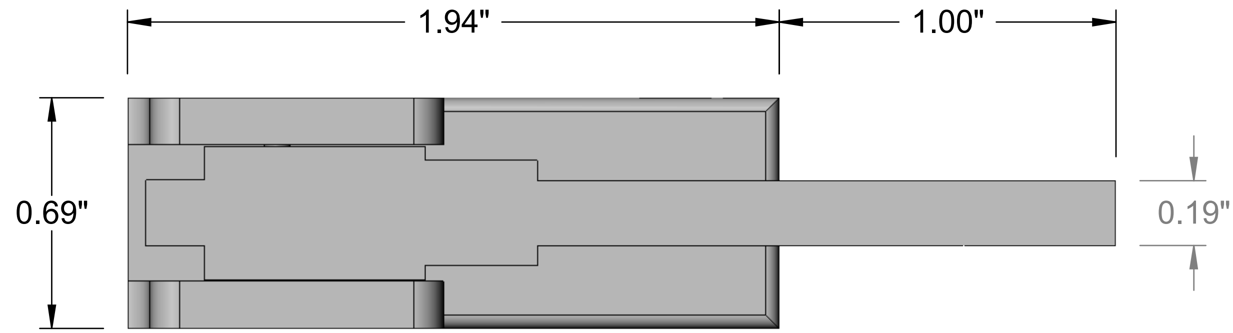


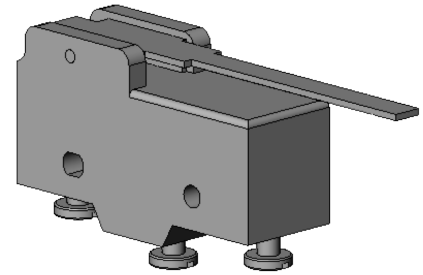


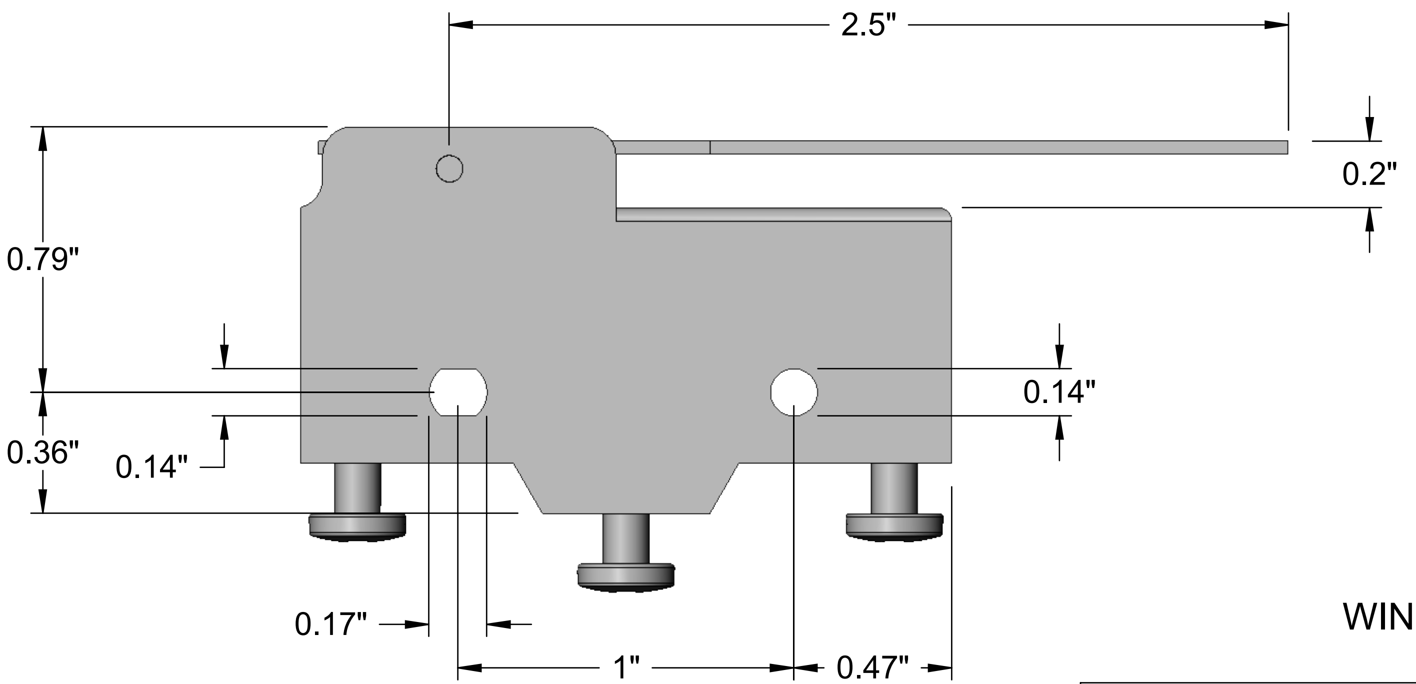
NOTES:

ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: TOWER HOUSING TUBE		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B210	Nxt Asb: B200	Date:5/29/2018	Scale: 1:6	Chkd. By: JULIA TRENKLE

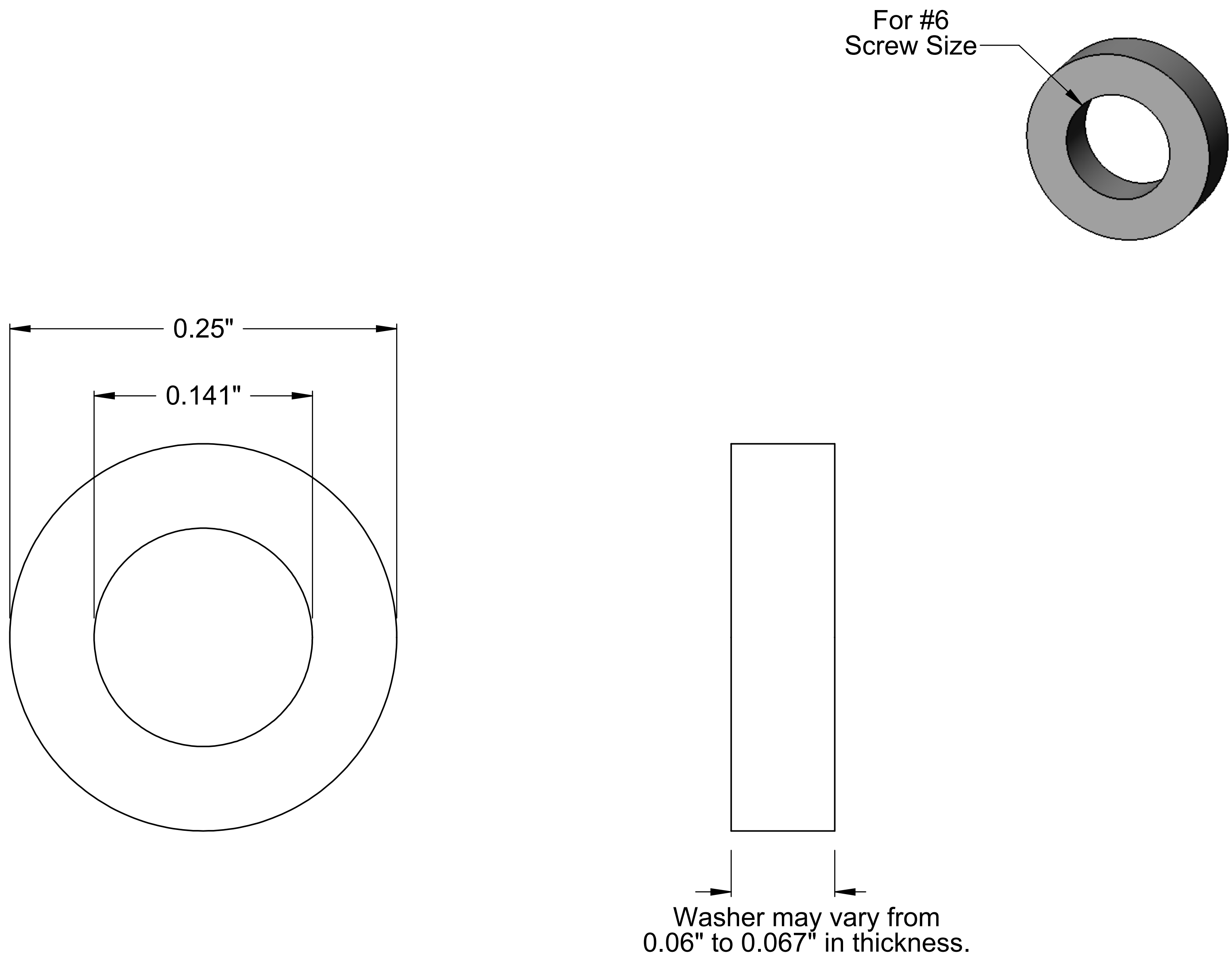






WINE OPENER P/N: B211

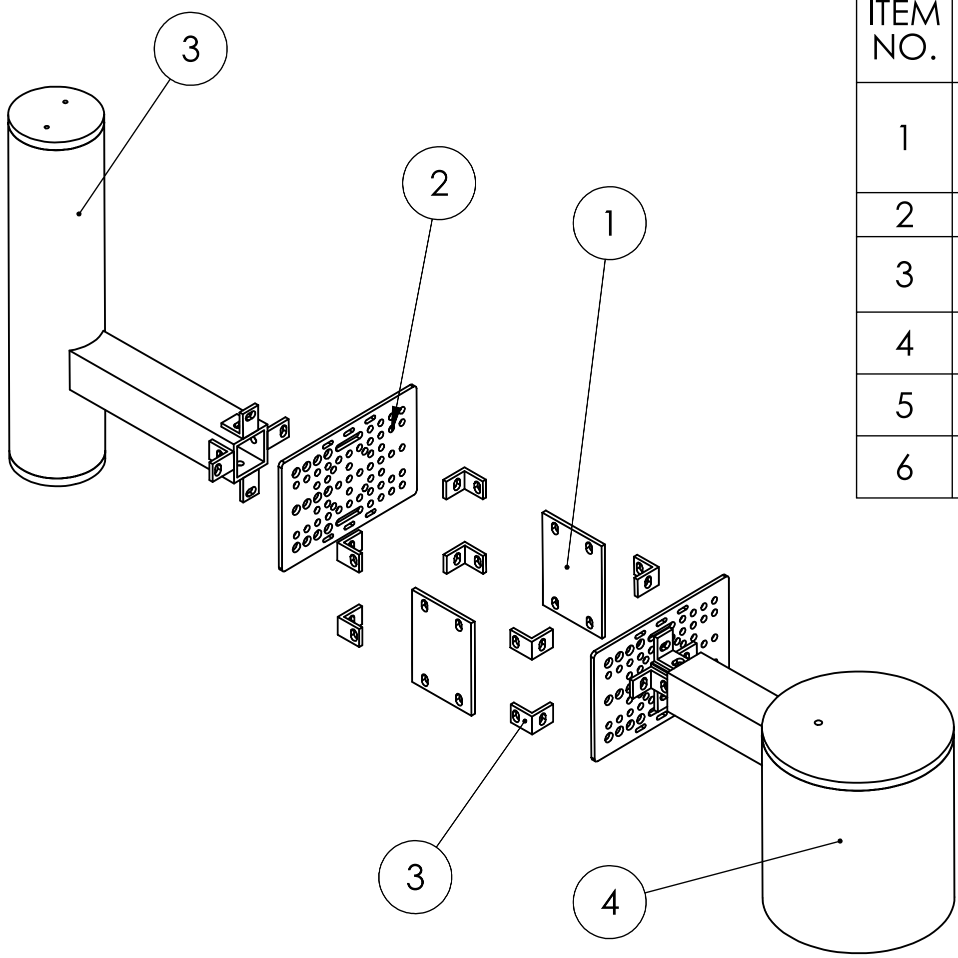
McMASTER-CARR® CAD	PART NUMBER	7090K37
http://www.mcmaster.com © 2012 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Rigid Lever Snap-Acting Switch	



WINE OPENER P/N: B212

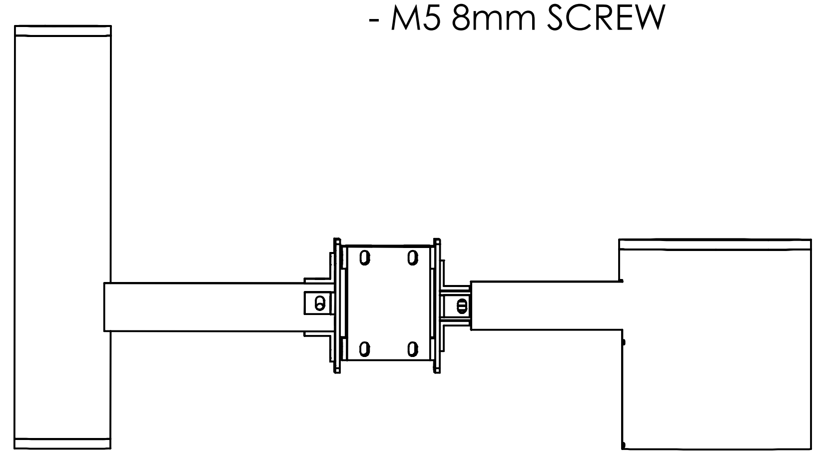
McMASTER-CARR® CAD	PART NUMBER 93650A100
http://www.mcmaster.com © 2017 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Moisture-Resistant Cushioning Washer

ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B301	PLATES WITH MOUNTING HOLES	ALUM.	2
2	B303	V-SLOT GANTRY SET	--	2
3	B500	CORK REMOVER	--	1
4	B400	FOIL CUTTER	--	1
5	B204	L BRACKET SINGLE	--	8
6	B113	FASTENER COMBINATION	--	16



6

PARTS NOT SHOWN:
B103 FASTNER COMBINATION
-TEE NUT
- M5 8mm SCREW

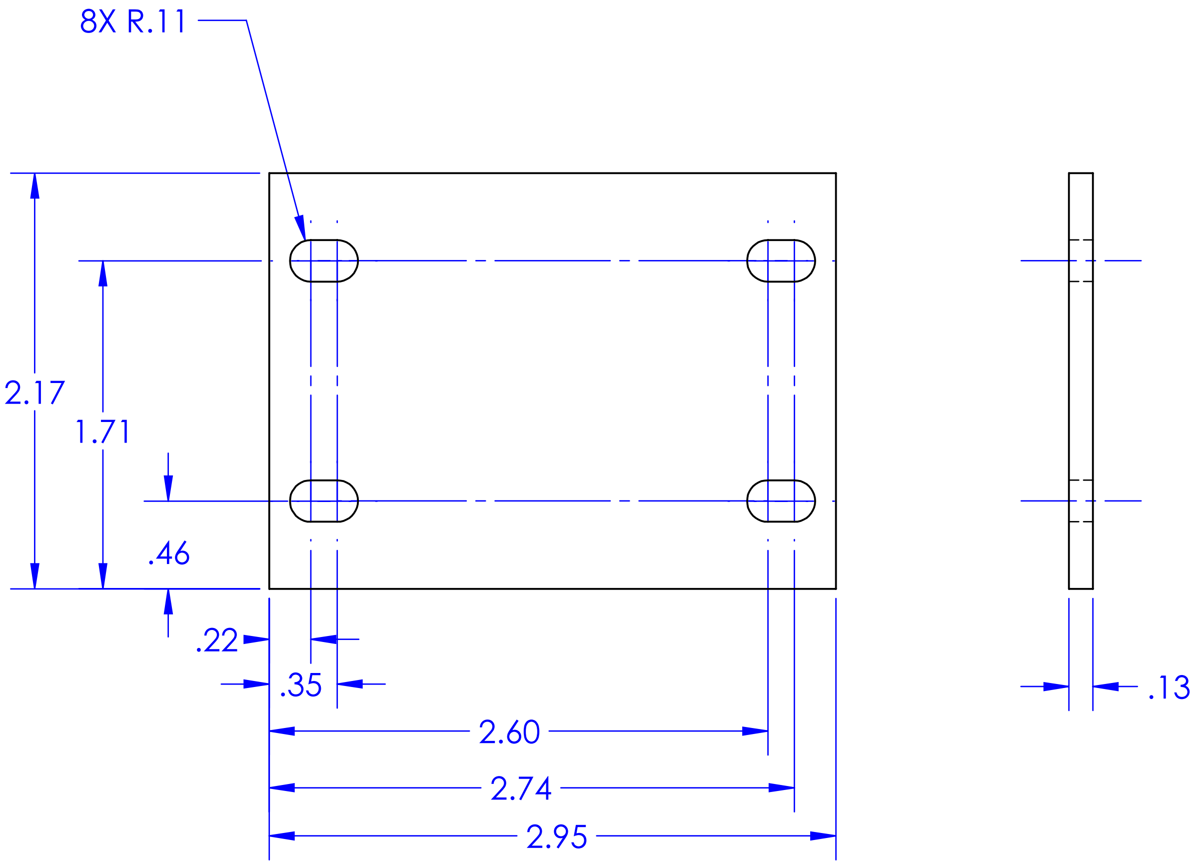


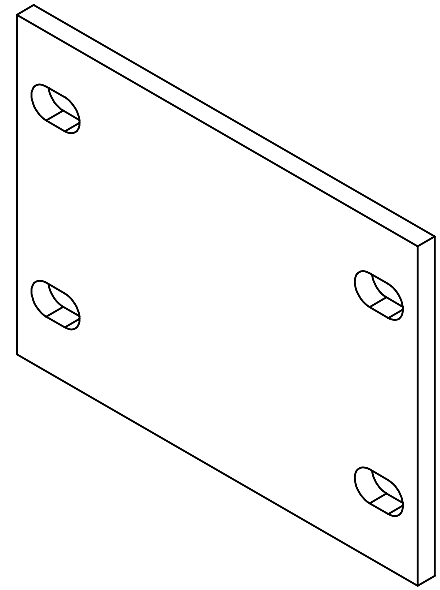
MANUFACTURED/ MODIFIED PARTS
B301
B500
B400

PURCHASED PARTS
B303
B204
B113

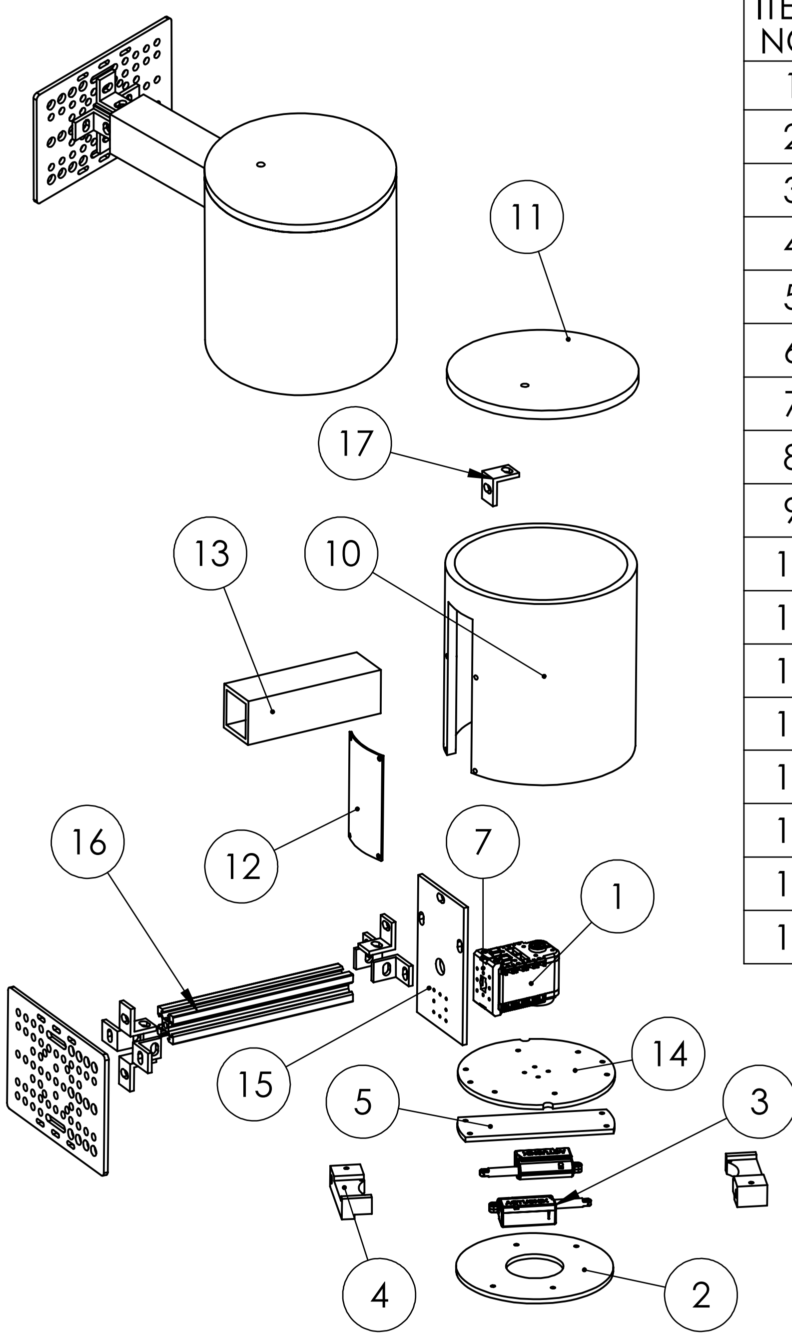
Cal Poly Mechanical Engineering SENIOR DESIGN	Material: SEE BOM		Title: FLOATING GANTRY SUBASSEMBLY	Drwn. By: JULIA TRENKLE
	Dwg. #: B300	Nxt Asb: A100	Date: 2/9/2018	Scale: 1:5	Chkd. By: BRETT WITTMUSS

NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.





Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM	Title: PLATES WITH MOUNTING HOLES	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B301 / Nxt Asb: B300	Date:5/29/2018 / Scale: 1:1	Chkd. By: JULIA TRENKLE



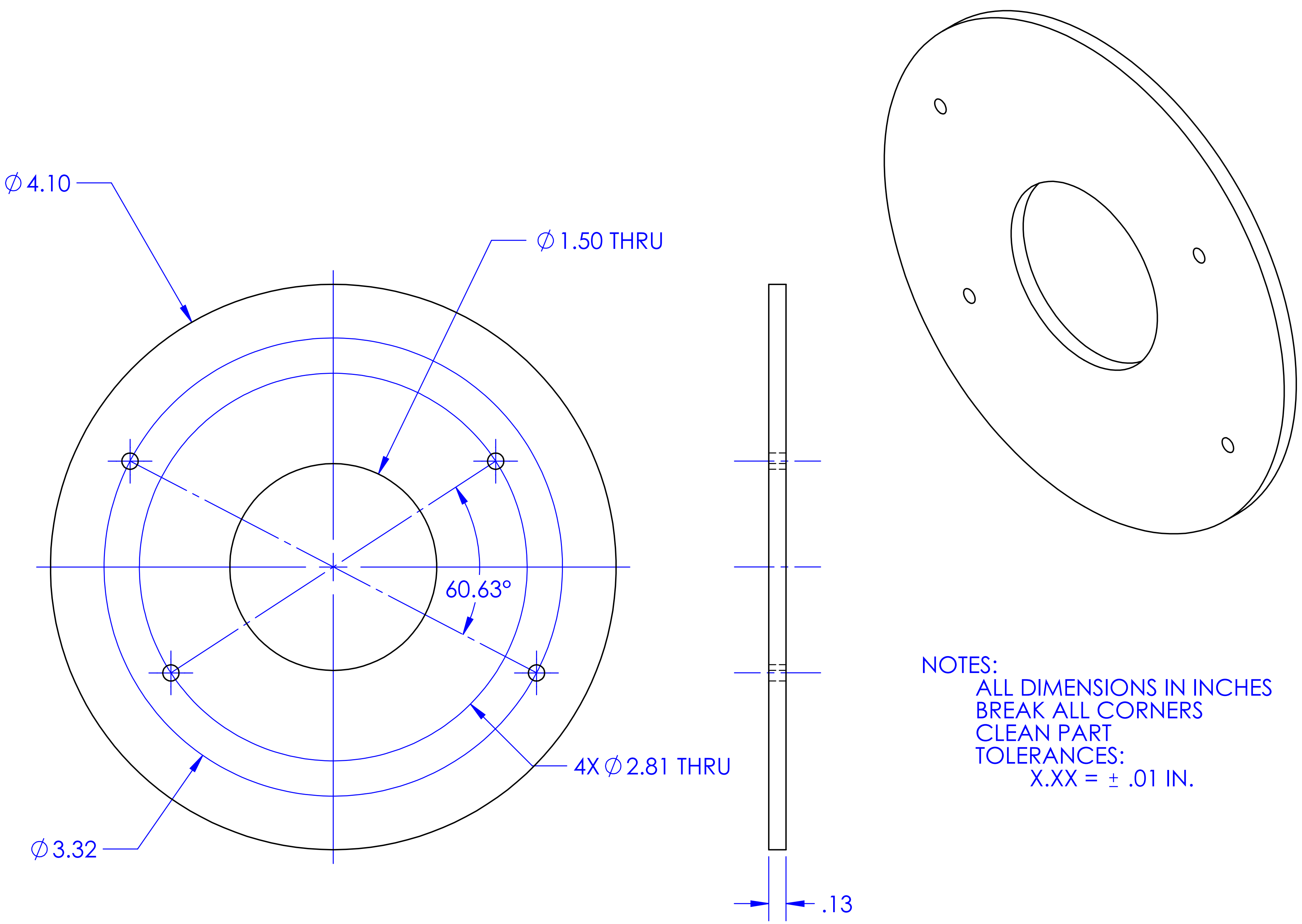
ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B203	DYNAMIXEL AX-12A	--	1
2	B401	FOIL CUTTER BOTTOM CAP	ALUM.	1
3	B402	FOIL CUTTER LINEAR SERVO	--	2
4	B403	FOIL CUTTER HOLDER	NYLON	2
5	B404	FOIL CUTTER RAIL	ACRYLIC	1
6	B405	SERRATED BLADE	--	2
7	B406	FASTENER COMBINATION		
8	B407	FASTENER	--	6
9	B408	FASTENER COMBINATION	--	8
10	B409	FOIL CUTTER HOUSING	--	8
11	B410	FOI LCUTTER HOUSING CAP	ALUM.	1
12	B411	FOIL CUTTER HOUSING COVER	ALUM.	1
13	B412	FOIL ARM HOUSING	ALUM.	1
14	B413	FOIL CUTTER TOP CAP	ALUM.	1
15	B414	FOIL CUTTER MOTOR PLATE	ALUM.	1
16	B102	LINEAR RAIL BASE V-SLOT	ALUM.	1
17	B204	L BRACKET	ALUM.	8

PURCHASED PARTS
B203
B402
B405
B406
B407
B408
B409
B204

MANUFACTURED/ MODIFIED PARTS
B401 B413
B403 B414
B404 B415
B410 B102
B411
B412

PARTS NOT SHOWN:
7 B407 FASTENER COMBINATION
-M3 HEX NUT
- M3 20mm SCREW
8 B408 FASTENER
- M3 8 mm SCREW
9 B409 FASTENER COMBINATION
-M2 HEX NUT
- M2 12mm SCREW
6 B405 SERRATED BLADE

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: SEE BOM		Title: FOIL CUTTER		Drwn. By: BRETT WITTMUSS
	Dwg. #: B400	Nxt Asb: A100	Date: 5/30/2018	Scale: 1:5	Chkd. By: JULIA TRENKLE



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: 6061 ALUMINUM		Title: FOIL CUTTER BOTTOM CAP		Drwn. By: BERKELEY DAVIS
	Dwg. #: B401	Nxt Asb: B400	Date:5/29/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE

Wine Opener P/N: B402

Miniature Linear Motion Series · PQ12

PQ12 Actual Size

Actuonix Motion Devices unique line of Miniature Linear Actuators enables a new generation of motion-enabled product designs, with capabilities that have never before been combined in a device of this size. These tiny linear actuators are a superior alternative to designing your own push/pull mechanisms. Their low cost and easy availability make them attractive to hobbyists and OEM designers alike.

The PQ12 actuators are complete, self contained linear motion devices with position feedback for sophisticated position control capabilities, or end of stroke limit switches for simple two position automation. Driving them couldn't be easier, simply apply a DC voltage to extend the actuator, and reverse the polarity to retract it. Several gear ratios and voltage options are available to give you varied speed/force configurations.

Benefits

- → **Compact miniature size**
- → **Precise position feedback**
- → **Limit switches**
- → **Simple control**
- → **Low voltage**
- → **Equal push/pull force**
- → **Easy mounting**

Applications

- → **Robotics**
- → **Consumer appliances**
- → **Toys**
- → **RC vehicles**
- → **Automotive**
- → **Industrial Automation**

PQ12 Specifications

Gearing Option	30:1	63:1	100:1
Peak Power Point	15N@15mm/s	30N @ 8mm/s	40N @ 6mm/s
Peak Efficiency Point	8N @ 20mm/s	12N@12mm/s	20N @ 8mm/s
Max Speed (no load)	28mm/s	15mm/s	10mm/s
Max Force (lifted)	18N	45N	50N
Max Side Load	5N	10N	10N
Back Drive Force	9N	25N	35N

Stroke	20 mm
Input Voltage	6 or 12 VDC
Stall Current	550mA @ 6V, 210mA @ 12V
Mass	15g
Operating Temperature	-10°C to +50°C
Positional Repeatability	±0.1mm
Mechanical Backlash	0.25 mm
Audible Noise	55dB @ 45cm
Ingress Protection	IP-54
Feedback Potentiometer	5kΩ±50%
Limit Switches	Max. Current Leakage: 8uA
Maximum Duty Cycle	20%

Basis of Operation

The PQ12 is designed to push or pull a load along its full stroke length. The speed of travel is determined by the load applied (see load curves). When power is removed the actuator will hold its position, unless the applied load exceeds the back drive force. Repeated stalling of the actuator against a fixed load will shorten the life of the actuator. Since application conditions (Environmental, loading, duty cycle, vibration, etc) vary so widely, we advise application specific testing to determine the expected life of the actuator.

Ordering

Small quantity orders can be placed directly online at www.Actuonix.com. Each actuator ships with two mounting brackets, M3 mounting hardware, and one FPC ribbon cable connector. To extend the length of the ribbon cable you can purchase one of our PQ12 cable adapters and extension cable, or solder wires directly to the ribbon cable. Contact sales@Actuonix.com for volume quotes and customization options for OEM's.

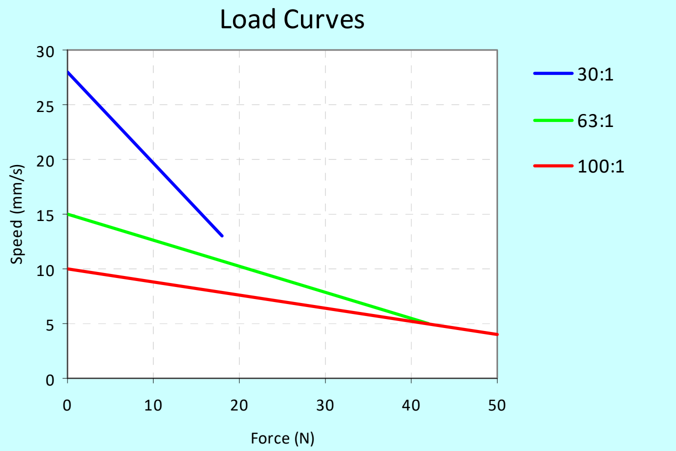
ACTUONIX MOTION DEVICES INC.

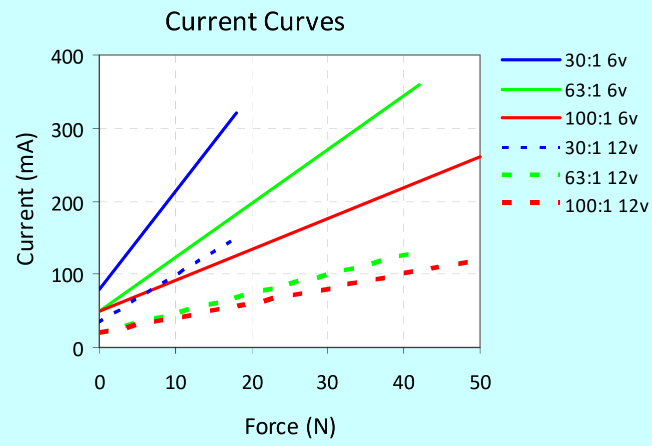
Actuonix Motion Devices Inc
580 Starling Lane
Victoria, BC, V9E 2A9
Canada

1 (206) 347-9684 *phone*
1 (888) 225-9198 *toll-free*
1 (206) 347-9684 *fax*

sales@actuonix.com
www.actuonix.com

PQ12 Specifications





Model Selection

The PQ12 has 3 configuration choices: Gear Ratio, Voltage and Controller. PQ12 options are identified according to the following scheme:

PQ12-GG-VV-C

feature	*options*
GG: Gear reduction ratio (refer to load curves above)	**30**, **63**, **100** (lower ratios are faster but push less force, and vice versa)
VV: Voltage	**6**, **12** (DC volts)
C: Controller	**P** Potentiometer Feedback **S** Limit Switches **R** RC Linear Servo (6V Only)

PQ12 Controller Options

Option S – End of Stroke Limit Switches

WIRING: (see next page for pin numbering)

1- Limit Switch Detection (Optional)
2- Actuator Motor Power
3- Actuator Motor Power
4- Not Connected
5- Not Connected

The –S actuators have limit switches that will turn off power to the motor when the actuator reaches within 1mm of the end of stroke. Internal diodes allow the actuator to reverse away from the limit switch. The limit switches cannot be moved. While voltage is applied to the motor power pins (2 & 3) the actuator extends. Reverse the polarity and the actuator retracts. This can be accomplished manually with a DPDT switch or relay, or using an H-Bridge circuit. The –S model cannot be used with the LAC control board. Pin #1 can be used to sense when the actuator has reached the end limits. See our FAQ page for a simple schematic to light an LED when the limits are reached.

Option P – Potentiometer Position Feedback

WIRING: (see next page for pin numbering)

1 – Feedback Potentiometer negative reference rail
2 – Actuator Motor Power
3 – Actuator Motor Power
4 – Feedback Potentiometer positive reference rail
5 – Feedback Potentiometer wiper

The –P actuators have no built in controller, but do provide analog position feedback. While voltage is applied to the motor power pins (2 & 3) the actuator extends. Reverse the polarity and the actuator retracts. Position of the actuator stroke can be monitored using the internal linear potentiometer. Provide any stable low and high reference voltage on pins 1 & 4, then read the position signal on pin 5. The voltage on pin 5 will vary linearly between the two reference voltages in proportion to the position of the actuator stroke. Connect to an LAC board for easy interface with any of the following control signals: Analog 0-5V or 4-20mA, or Digital 0-5V PWM, 1-2ms Standard RC, or USB.

Option R – RC Linear Servo

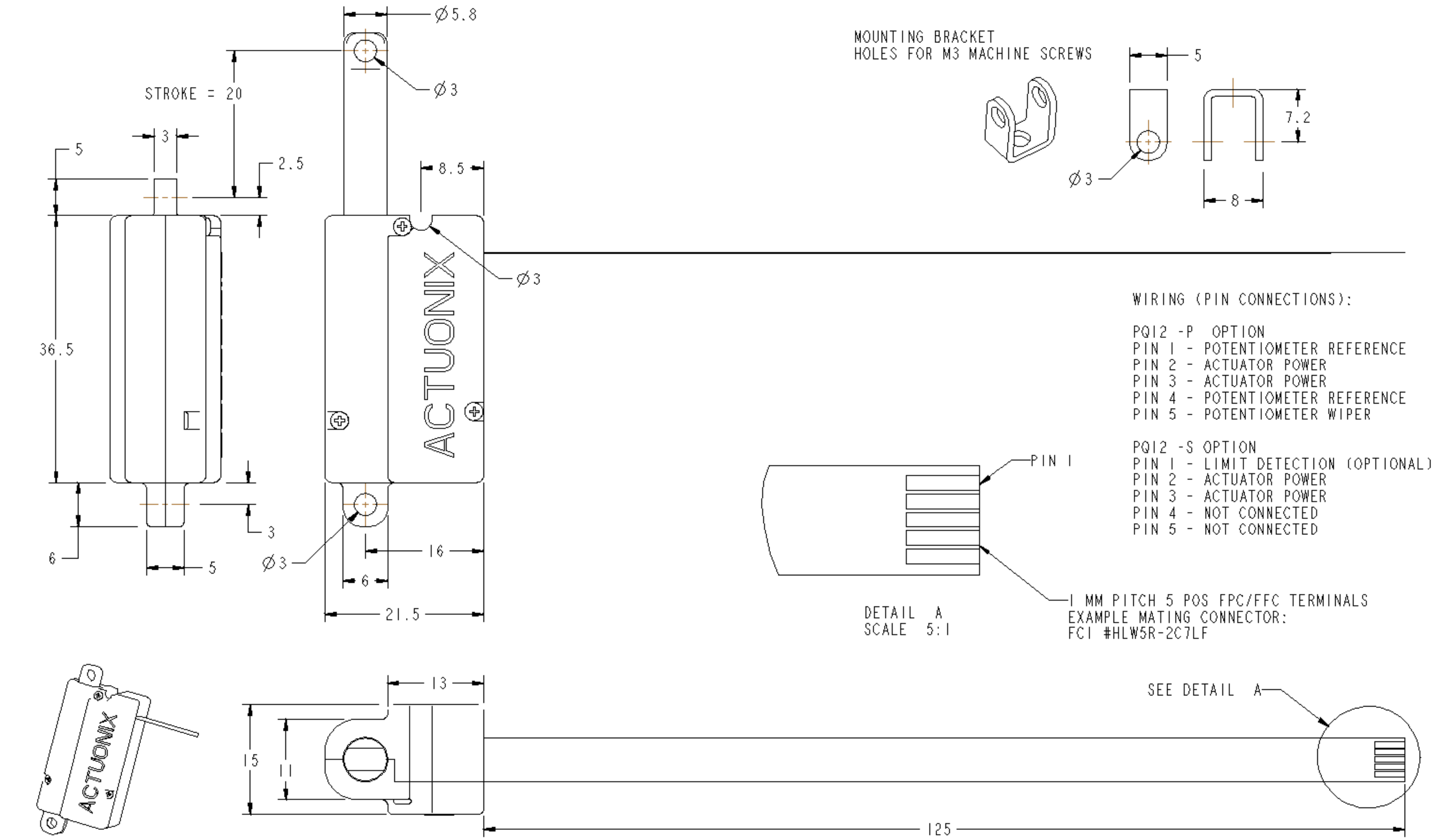
WIRING: (see last page for pin numbering)

1 - RC input signal (RC-servo compatible)
2 - Power (+6 VDC)
3 - Ground

Note: Reversing polarity on pins 2 and 3 may cause damage

-R actuators are ideally suited to use in robotics and radio control models. The –R actuators or 'linear servos' are a direct replacement for regular radio controlled hobby servos. The desired actuator position is input to the actuator on lead 1 as a positive 5 Volt pulse width signal. A 2.0 ms pulse commands the controller to fully retract the actuator, and a 1.0 ms pulse signals it to fully extend. If the motion of the actuator, or of other servos in your system, seems erratic, place a 1–4Ω resistor in series with the actuator's red V+ lead wire. The PQ12–R Linear Servos are designed to work with typical RC receivers and battery packs. Consequently, they also are compatible with Arduino control boards, VEX Microcontrollers and many other similar boards designed for robotics.

ACTUONIX MOTION DEVICES INC.
Actuonix Motion Devices Inc
580 Starling Lane
Victoria, BC, V9E 2A9
Canada
1 (206) 347-9684 *phone*
1 (888) 225-9198 *toll-free*
1 (206) 347-9684 *fax*
sales@actuonix.com
www.actuonix.com



ALL DIMENSIONS IN MILLIMETERS

Part #: B402

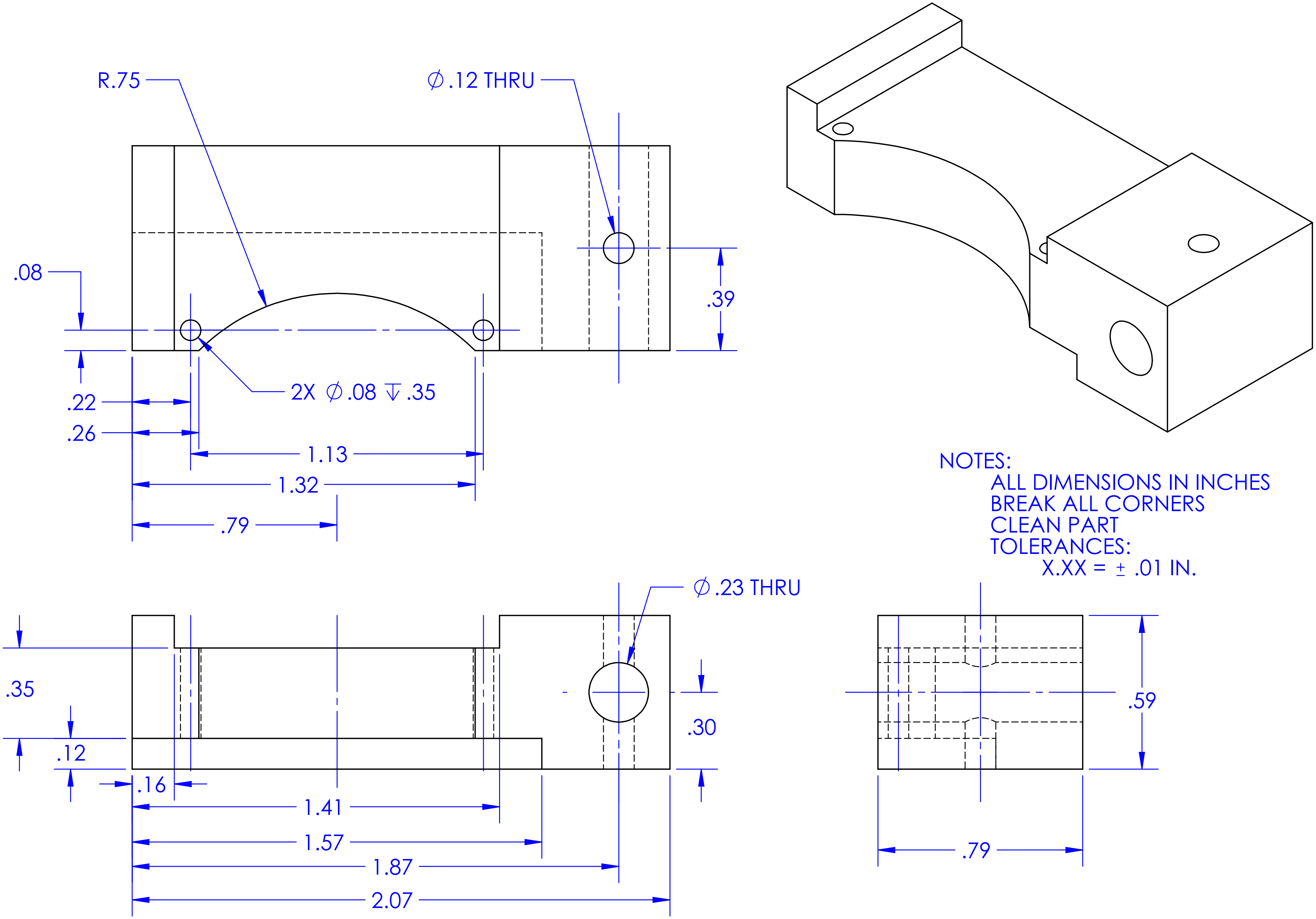
PQ12 ACTUATOR DIMENSIONS	ACTUONIX

Actuonix Motion Devices Inc
580 Starling Lane
Victoria, BC, V9E 2A9
Canada

1 (206) 347-9684 *phone*
1 (888) 225-9198 *toll-free*
1 (206) 347-9684 *fax*

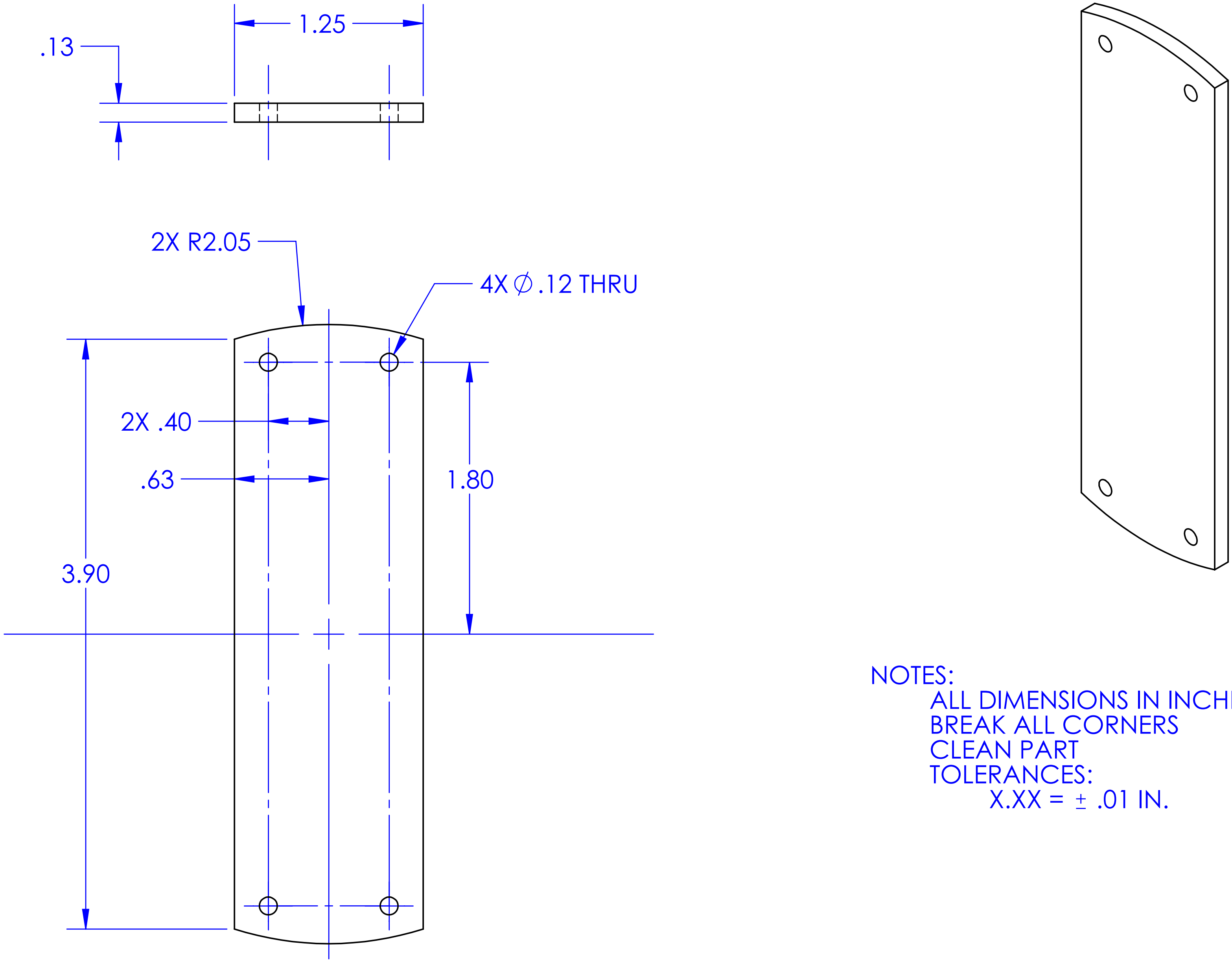
sales@actuonix.com
www.actuonix.com

Rev C. September 2016



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: NYLON		Title: FOIL CUTTER HOLDER	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B403	Nxt Asb: B400	Date:5/29/2018 / Scale: 2:1	Chkd. By: JULIA TRENKLE



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ACRYLIC	Title: BOTTLE SLEEVE RAIL	Drwn. By: BERKELEY DAVIS
	Dwg. #: B404 / Nxt Asb: B400	Date:5/29/2018 / Scale: 1:1	Chkd. By: JULIA TRENKLE

WINE OPENER P/N: B405

Roll over image to zoom in

HQY

2 Pack Premium Dual Blade Wine Foil Cutter - Wine Bottle Opener Accessory - Gift for Wine Lovers by HQY (Black &White)

359 customer reviews

Price: $6.99 prime

FREE Shipping on orders over $25—or get **FREE Two-Day Shipping** with Amazon Prime

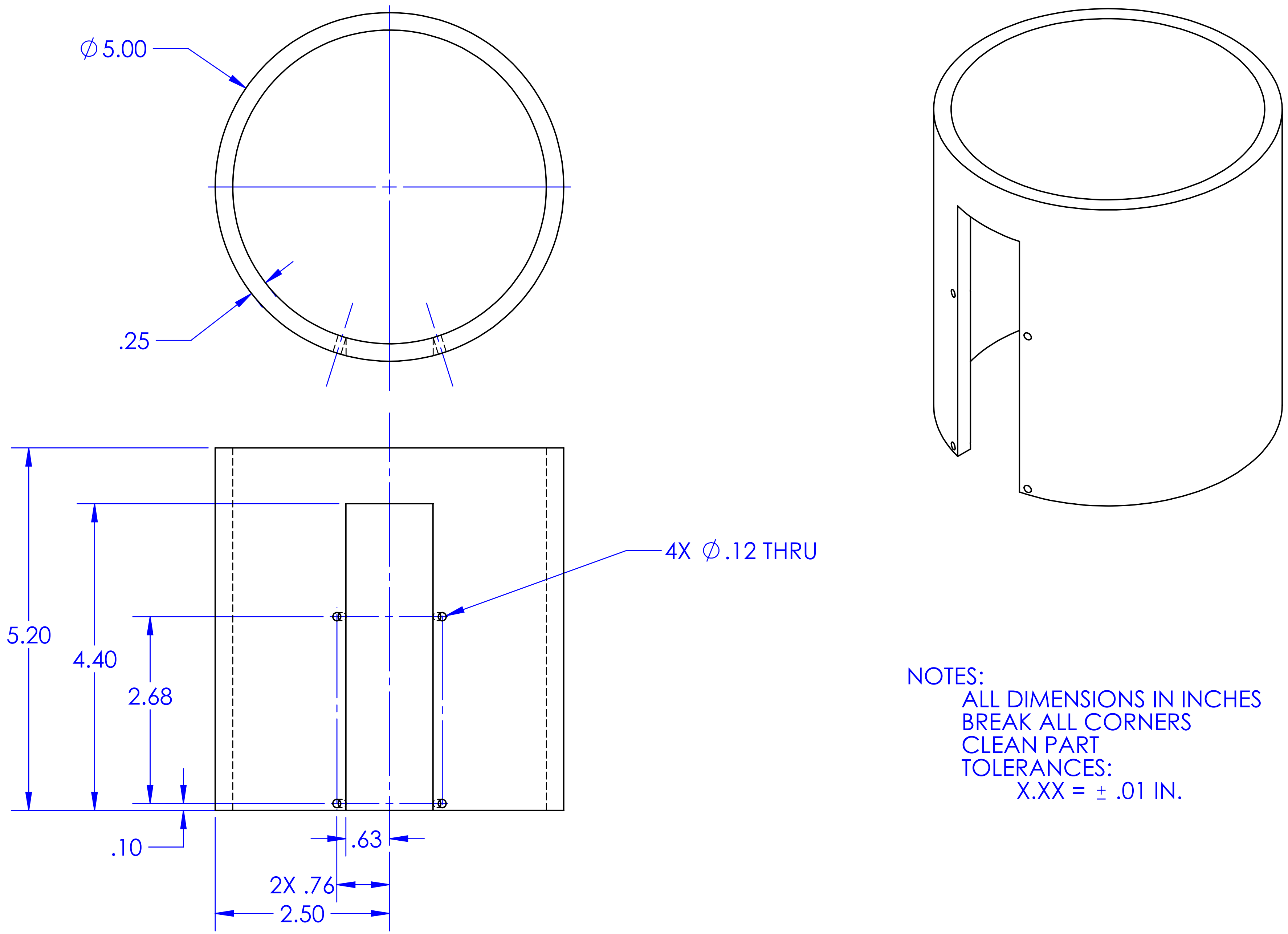
In Stock.

Want it Friday, June 1? Order within **3 hrs 7 mins** and choose **Two-Day Shipping** at checkout. Details

Sold by HQY Kitchen Tools and Fulfilled by Amazon. Gift-wrap available.

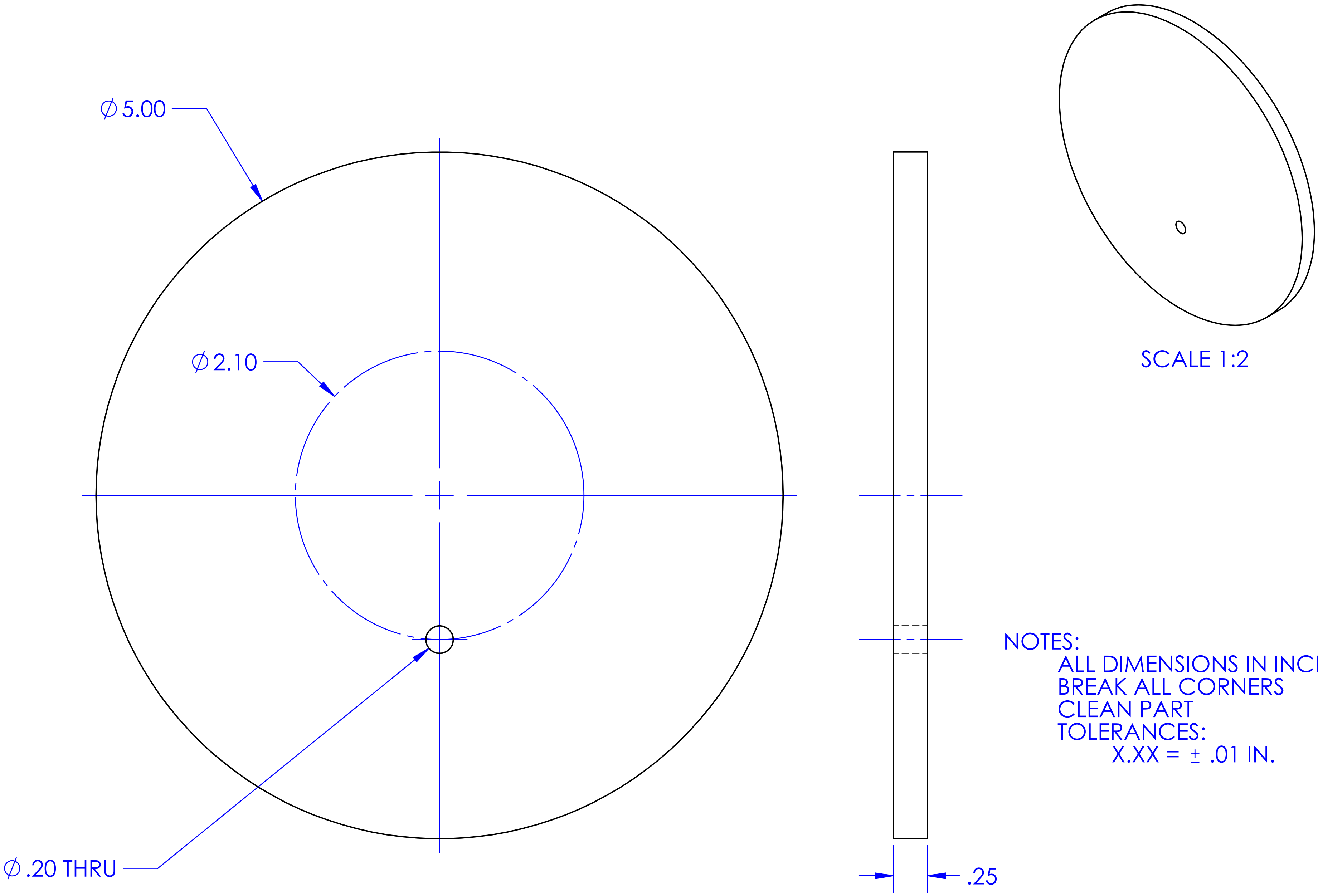
Color: **Black &White**

- A PERFECT WINE ACCESSORY STOCKING STUFFER: Looking for a unique gift for a Christmas, housewarming, birthday, anniversary, wedding or other party or event? The HQY Wine foil cutter is the best quality of Wine foil cutter.
- 5 STAR RATING: Thousands of wine lovers agree this beautiful, black& white color, HQY Wine foil cutter removes the foil top from your wine bottle effortlessly, leaving your glass bottle looking great and ready for cork removal.
- SIMPLE TO USE FOR EVERYONE: Ergonomically designed for comfort, your wine bottle foil top will be perfectly removed with just a quick and easy quarter turn of the wrist. Easy for all adults, even those with wrist and arthritis issues.
- STURDY AND STRONG: The HQY Wine foil cutter is strong, durable and flexible . Perfect for home bar accessories or as gift ideas.
- SAFE AND GUARANTEED: The foil remover is 100% guaranteed to make removing that foil from your wine bottle far simpler than using a knife or sharp edge of your wine opener, leading to safe and enjoyable, summer wine drinking! CLICK ADD TO CART!



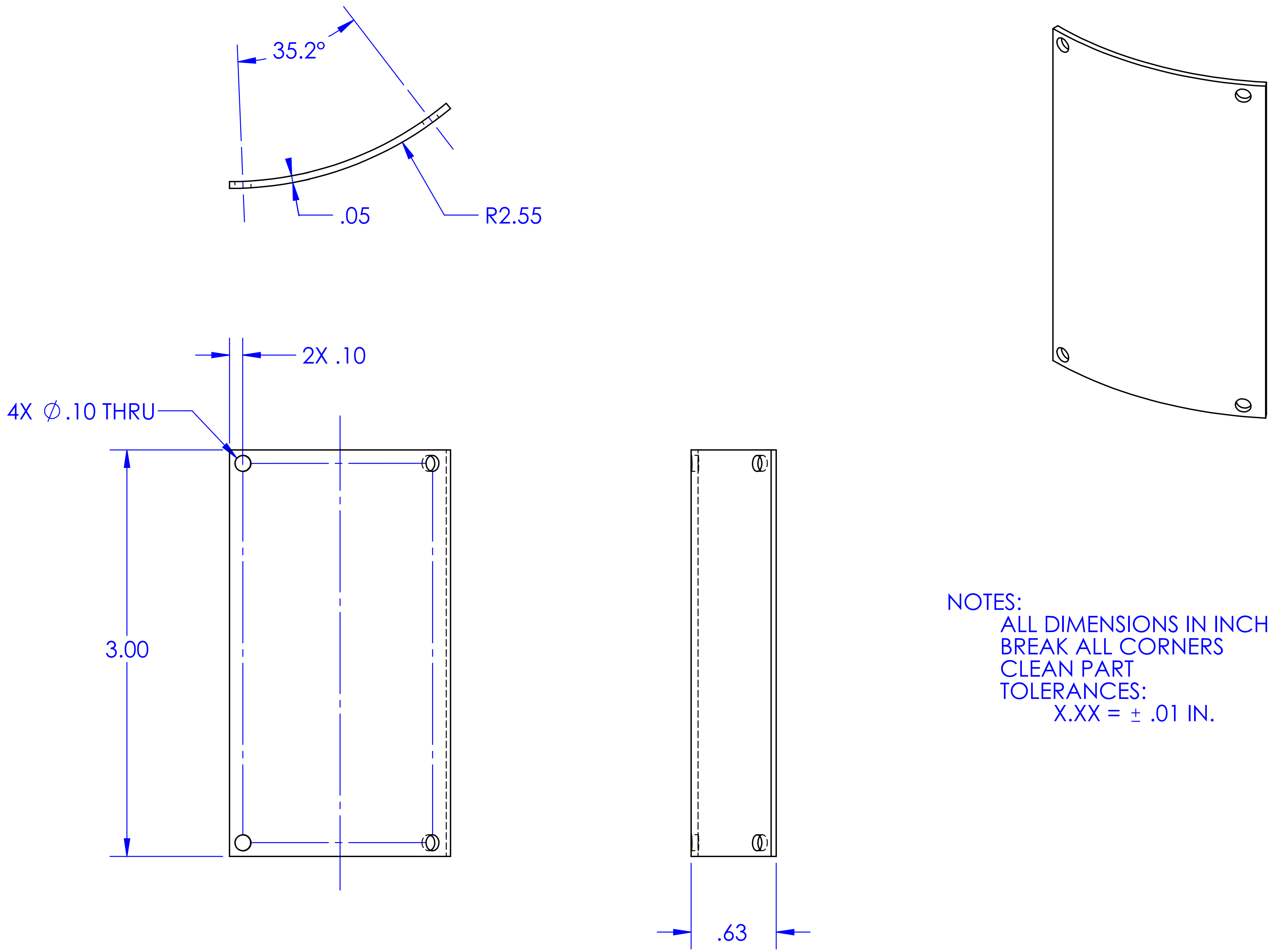
NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM	Title: FOIL CUTTER HOUSING	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B409 / Nxt Asb: B400	Date:5/29/2018 / Scale: 1:2	Chkd. By: JULIA TRENKLE



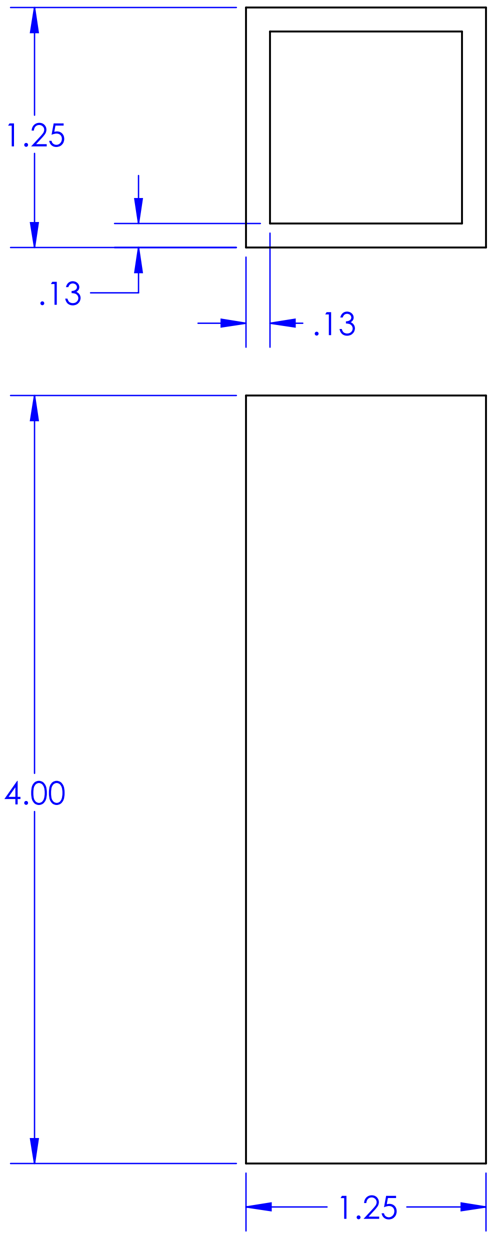
NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

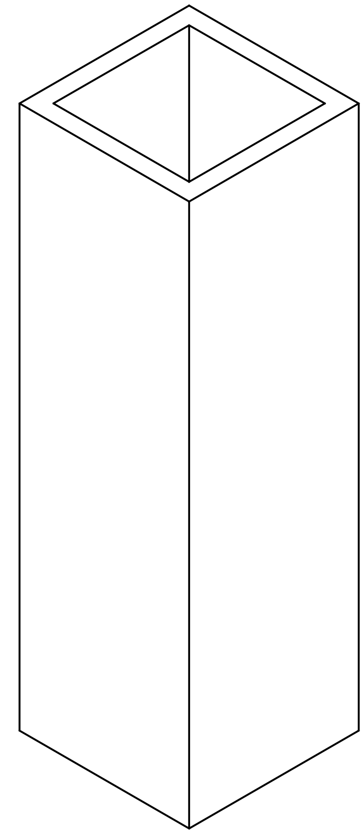
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: 6061 ALUMINUM		Title: FOIL CUTTER HOUSING CAP		Drwn. By: BERKELEY DAVIS
	Dwg. #: B410	Nxt Asb: B400	Date:5/29/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: FOIL CUTTER HOUSING COVER		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B411	Nxt Asb: B400	Date:5/29/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE

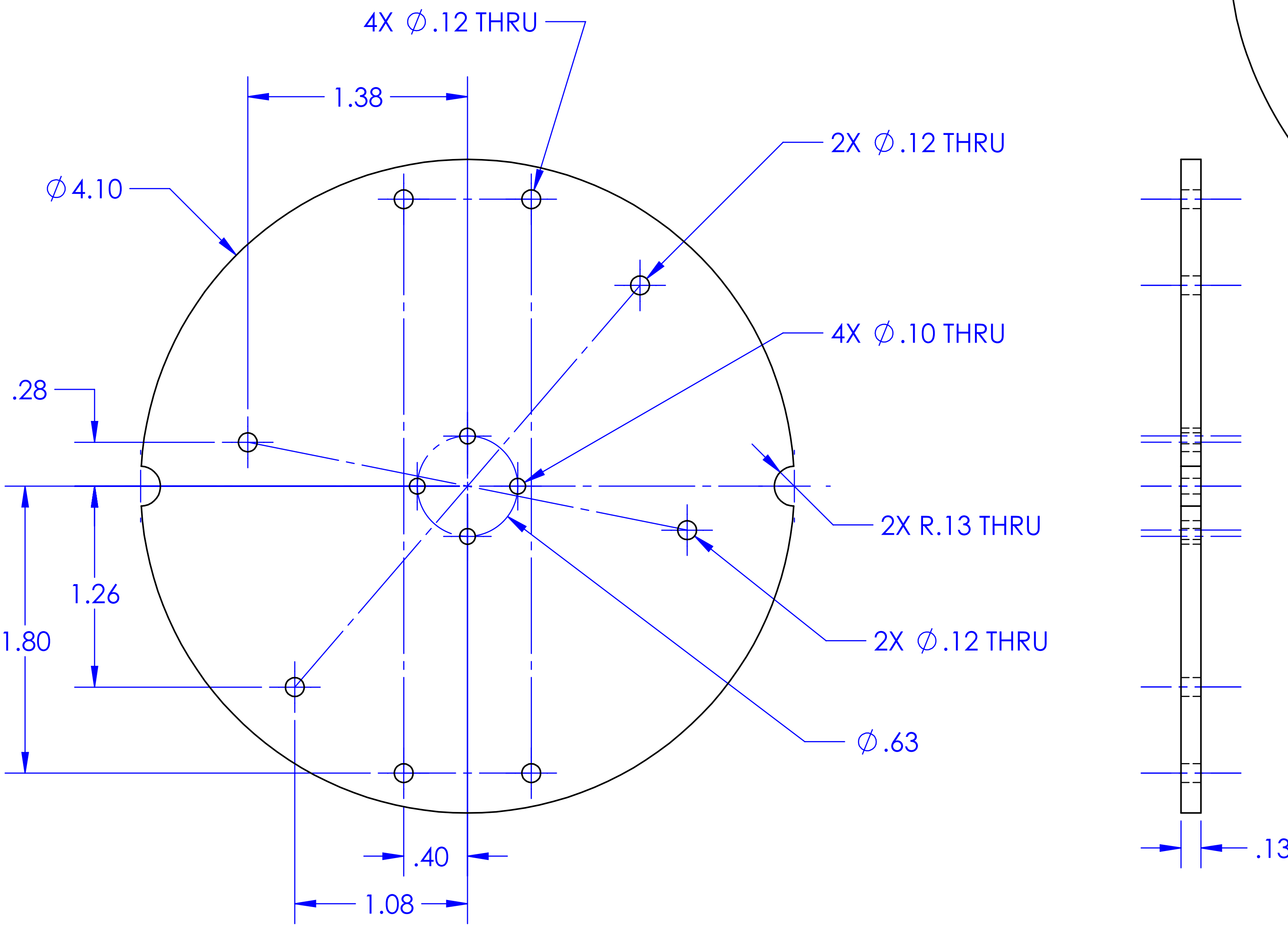


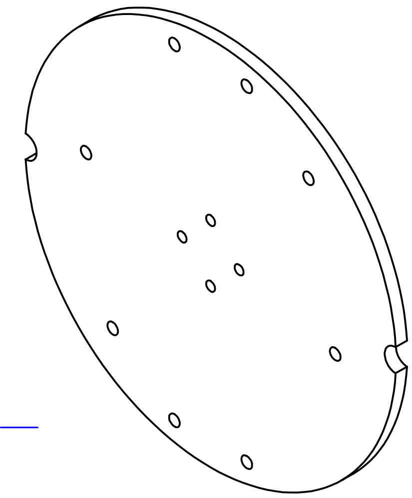


NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: ALUMINUM		Title: FOIL ARM HOUSING		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B412	Nxt Asb: B400	Date:5/30/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE

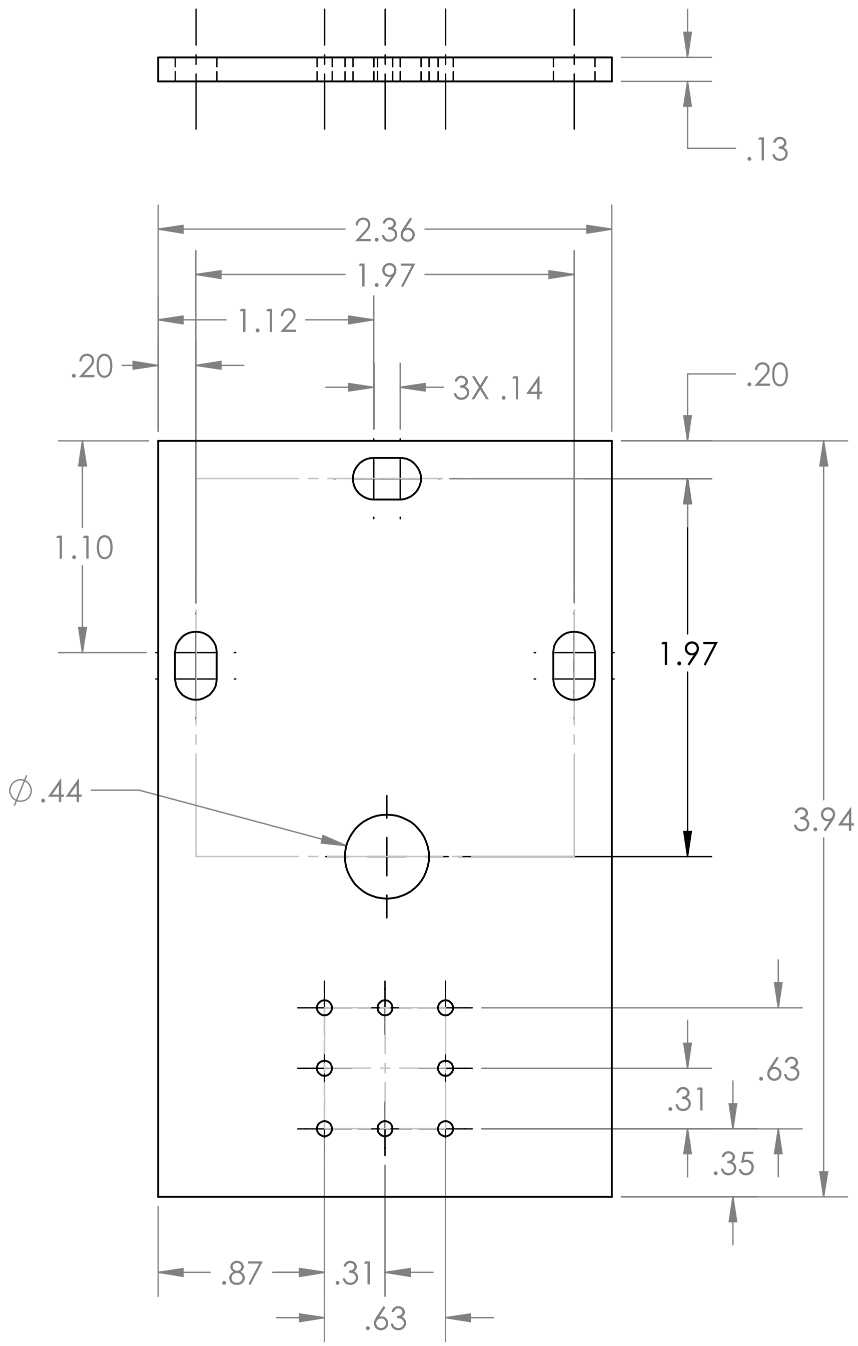
NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

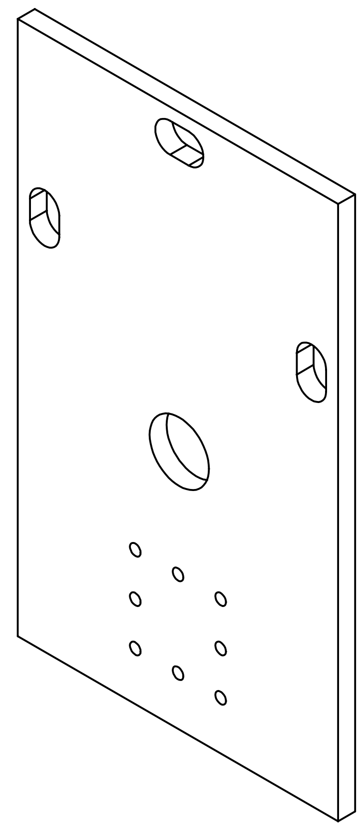




SCALE 2:3

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM	Title: FOIL CUTTER TOP CAP	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B413 / Nxt Asb: B400	Date:5/28/2018 / Scale: 1:2	Chkd. By: JULIA TRENKLE

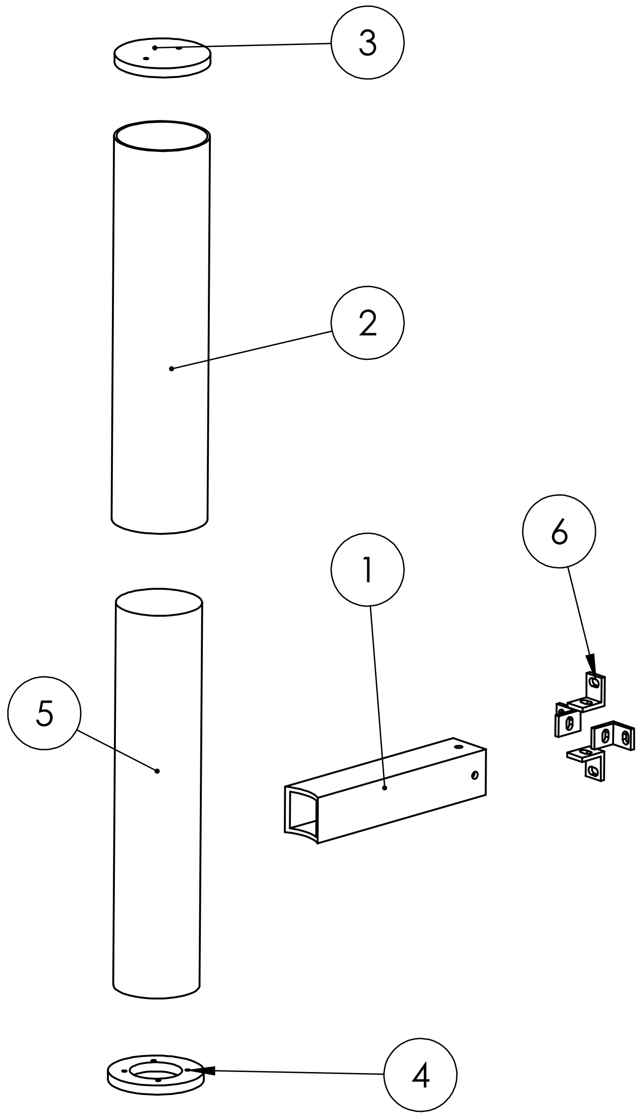


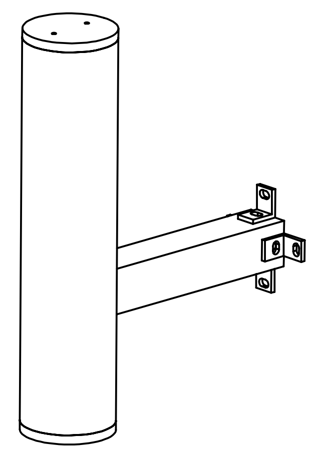


NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: FOIL CUTTER MOTOR PLATE		Drwn. By: BRETT WITTMUSS
SENIOR PROJECT	Dwg. #: B414	Nxt Asb: B400	Date: 2/9/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE

ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B501	CORKSCREW ARM HOUSING	ALUM.	1
2	B502	CORKSCREW HOUSING TUBE	ALUM.	1
3	B503	CORKSCREW HOUSING TOP	ALUM.	1
4	B504	CORKSCREW BOTTOM CAP	ALUM.	1
5	B505	ELECTRIC CORKSCREW	--	1
6	B204	L BRACKET	ALUM.	4
7	B506	FASTENER COMBINATION	--	4
8	B507	FASTENER COMBINATION	--	4
9	B508	FASTENER COMBINATION	--	6





PURCHASED PARTS
B505
B204
B506
B507
B508

MANUFACTURED/ MODIFIED PARTS
B501
B502
B503
B504

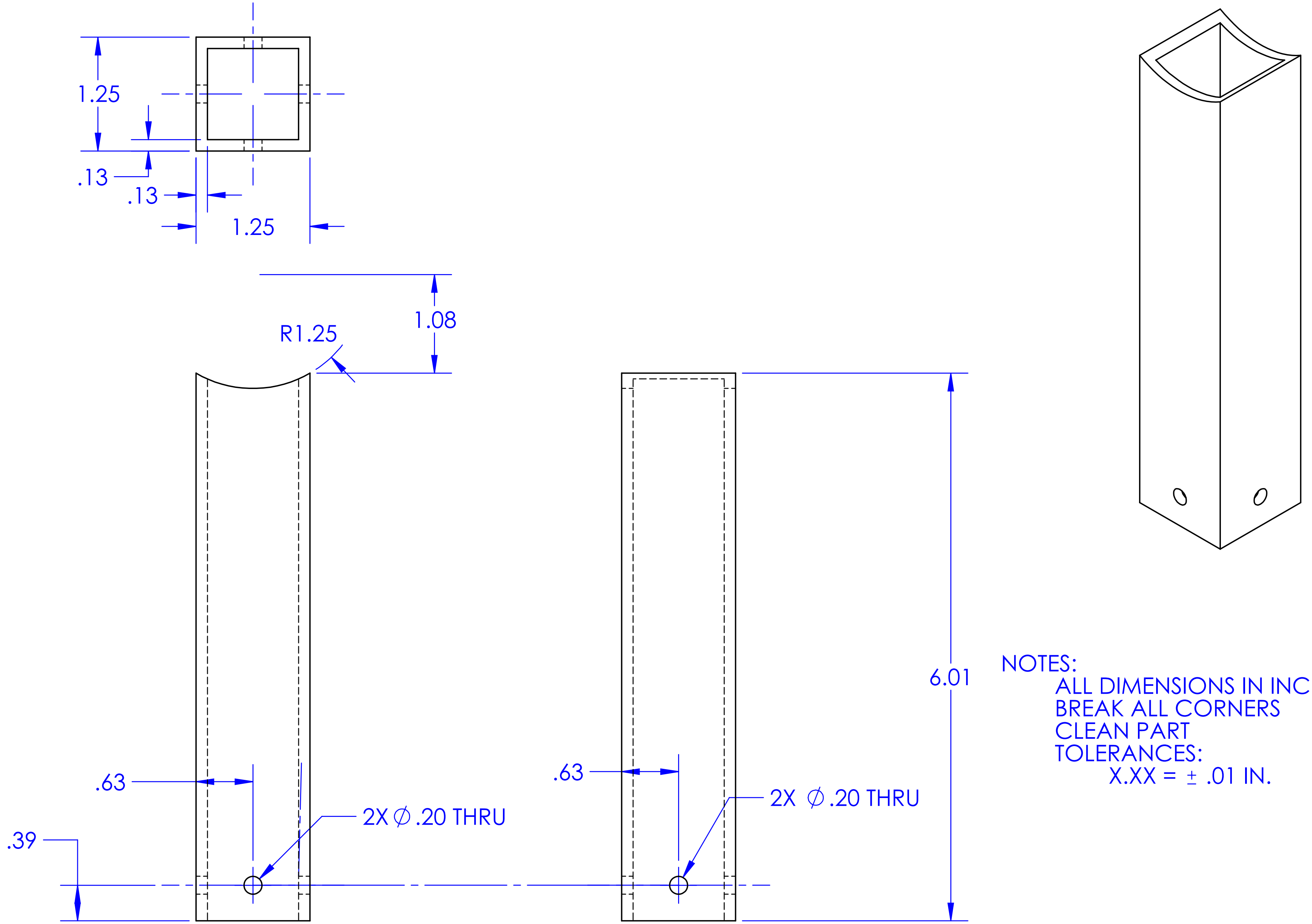
PARTS NOT SHOWN:

7 B506 FASTENER COMBINATION
-M5 HEX NUT
- M5 8mm SCREW

8 B507 FASTENER COMBINATION
- M5 12 mm SCREW
-M5 HEX NUT

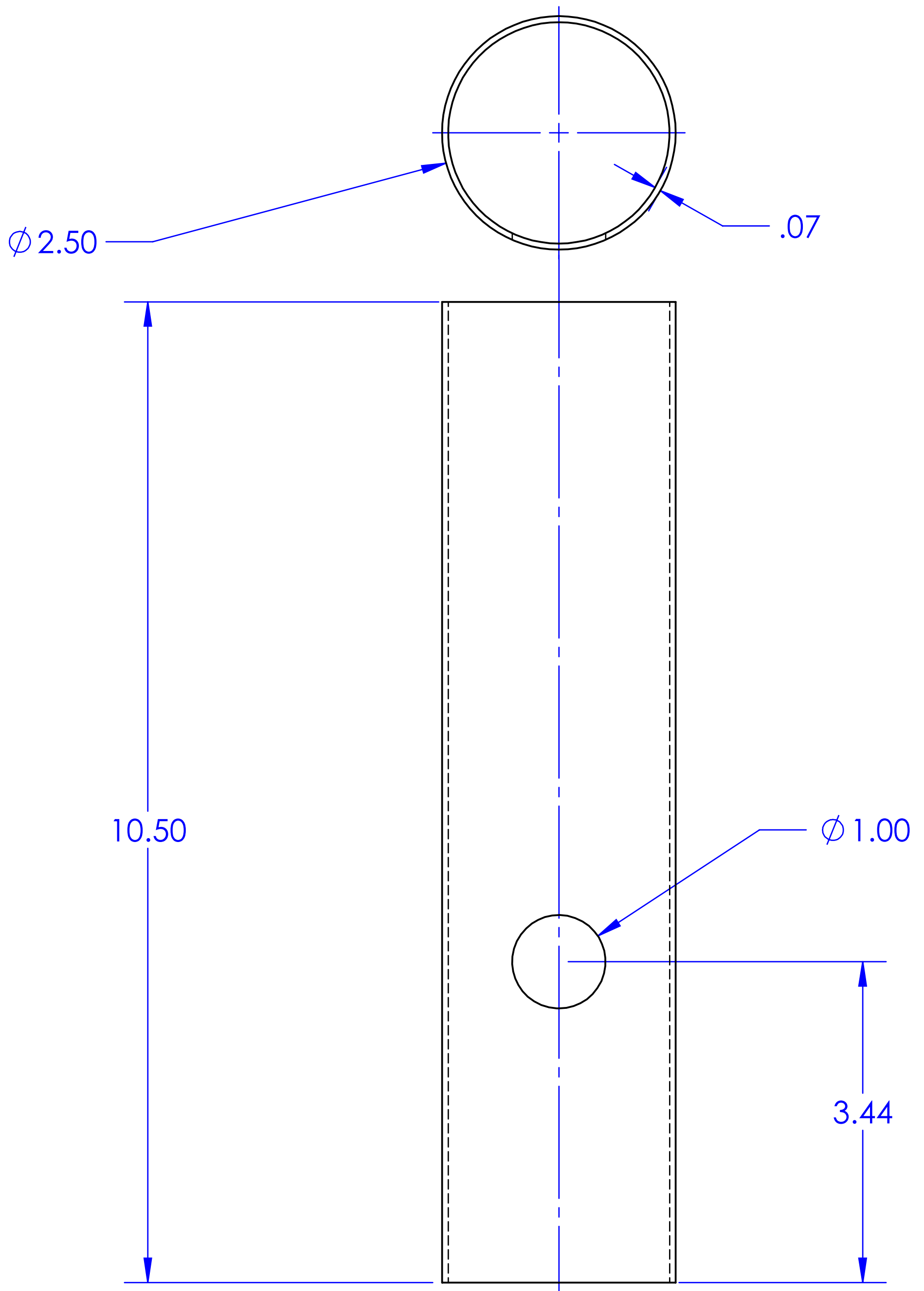
9 B508 FASTENER COMBINATION
-M3 20 mm SCREW

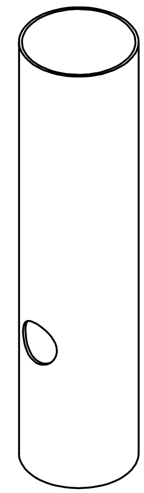
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: SEE BOM		Title:CORK REMOVER		Drwn. By: JULIA TRENKLE
	Dwg. #: B500	Nxt Asb: A100	Date: 5/30/2018	Scale: 1:5	Chkd. By: BERKELEY DAVIS



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: ALUMINUM		Title: CORKSCREW ARM HOUSING		Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B501	Nxt Asb: B500	Date:5/30/2018	Scale: 2:3	Chkd. By: JULIA TRENKLE



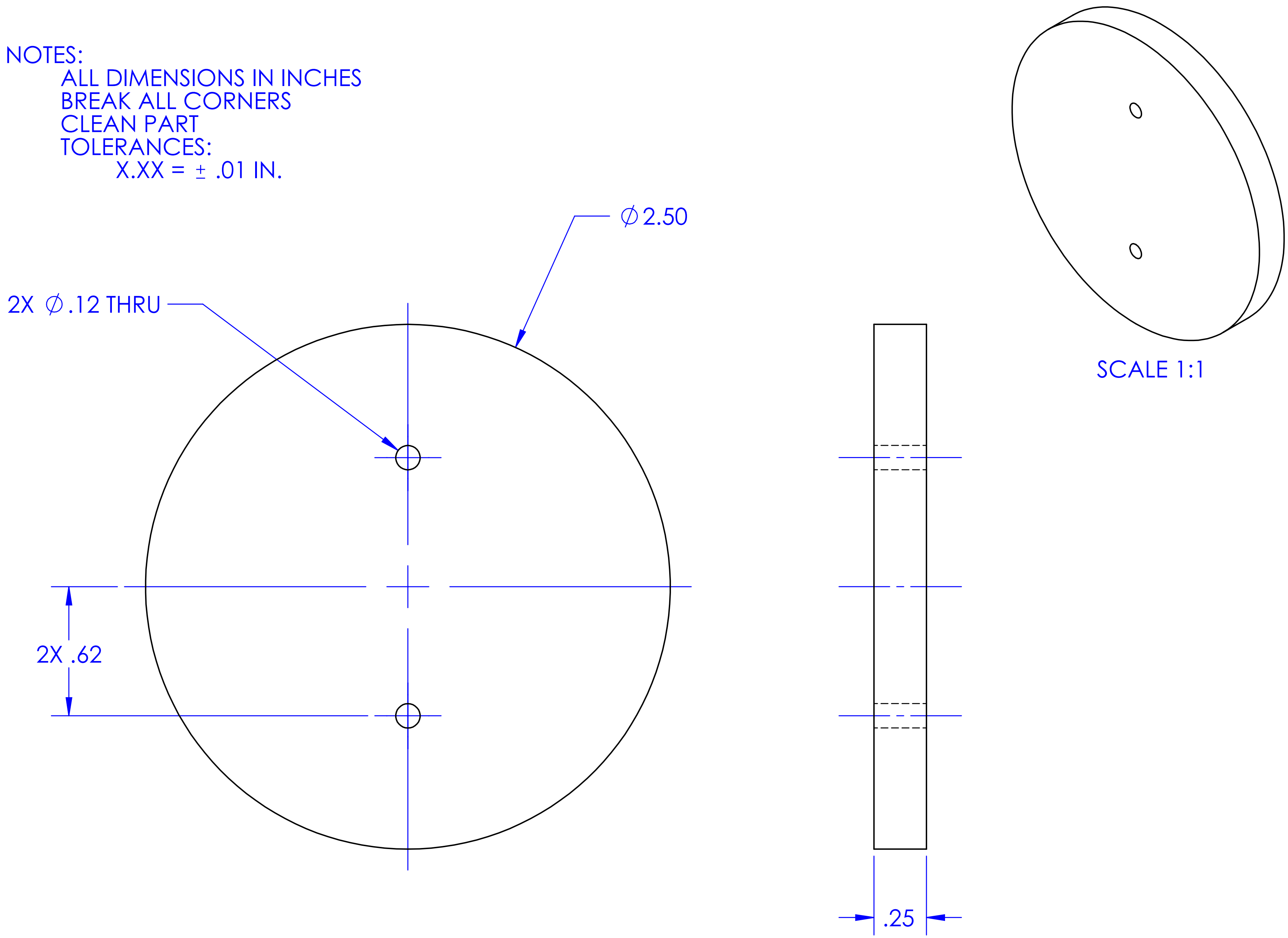


SCALE 1:4

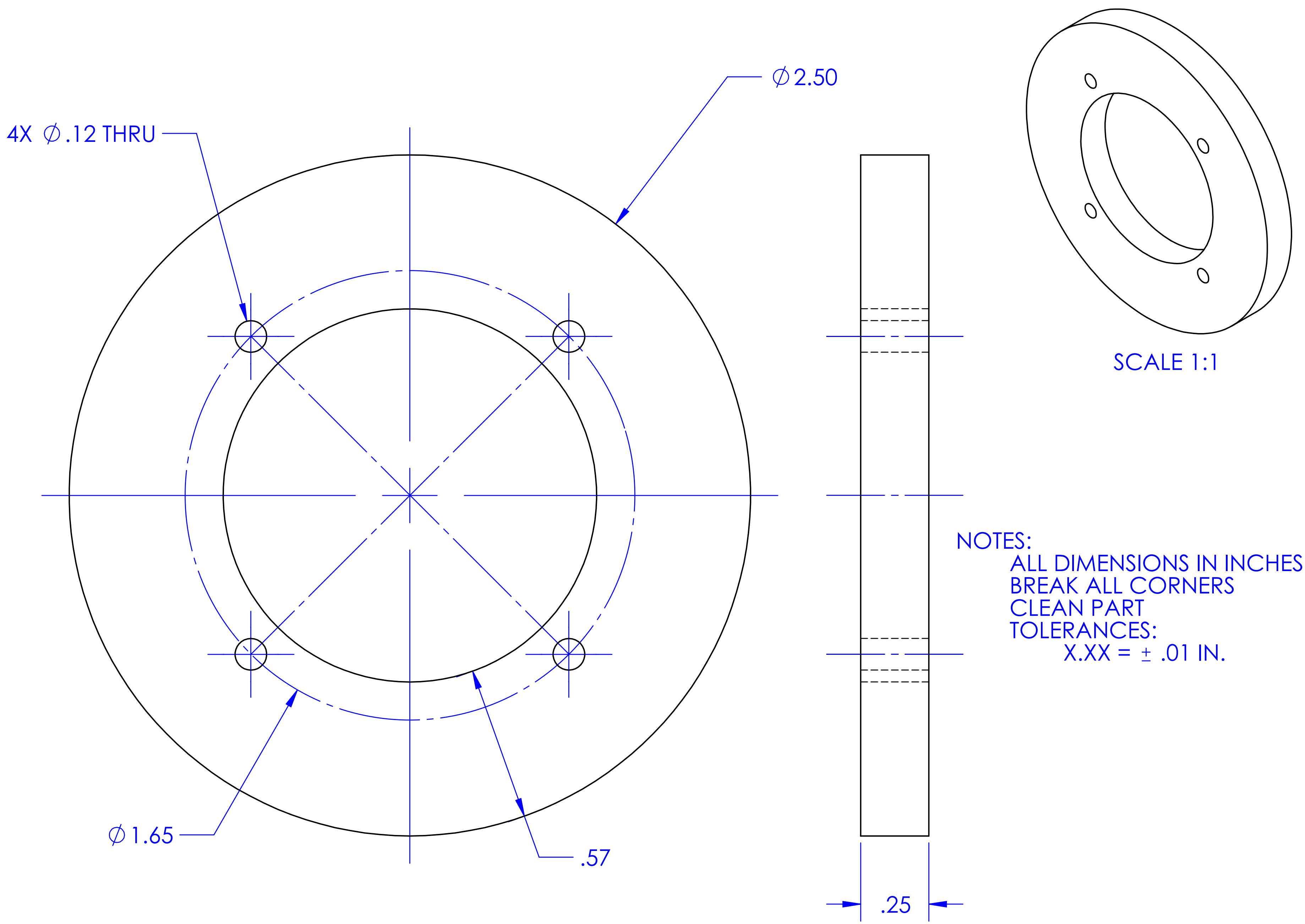
NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL CORNERS
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM		Title: CORKSCREW HOUSING T UBE	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B502	Nxt Asb: B500	Date:5/28/2018	Scale: 1:2	Chkd. By: JULIA TRENKLE

NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.



Cal Poly Mechanical Engineering	Material: 6061 ALUMINUM	Title: CORKSCREW HOUSING TOP	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B503 / Nxt Asb: B500	Date:5/28/2018 / Scale: 3:2	Chkd. By: JULIA TRENKLE



NOTES:
- ALL DIMENSIONS IN INCHES
- BREAK ALL CORNERS
- CLEAN PART
- TOLERANCES:
  - X.XX = ± .01 IN.

Cal Poly Mechanical Engineering	Material: ALUMINUM		Title: CORKSCREW BOTTOM CAP	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B504	Nxt Asb: B500	Date:5/30/2018	Scale: 2:1	Chkd. By: JULIA TRENKLE

WINE OPENER P/N: B505

Houdini Electric Corkscrew

shop all Houdini

about this item

details | shipping & returns | q&a | What's GiftNow?

Now, you can easily pull all types of corks, including synthetic. The Houdini Electric Corkscrew has a recessed spiral that lets you lock it on the bottle for easier operation. Simply press the down arrow to remove the cork and then press the up arrow to eject the cork.

Material: Stainless Steel, Plastic

Dimensions (Overall): 10.5 inches (H) x 2.25 inches (W) x 2.25 inches (L)

Weight: 1.2 pounds

Care and Cleaning: Spot or wipe clean

Power Source: Battery

Battery: 4 AA Alkaline, Required, included

TCIN: 52360339

UPC: 022578109091

Item Number (DPCI): 070-05-3816

Origin: Imported

ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B601	DRAWER HANDLE	--	2
2	B602	BASE PLATE	ALUM.	1
3	B603	ELECTRICAL BOX	ALUM.	1
4	B604	SPLASH SHIELD BASE	ACRYLIC	2
5	B605	SPLASH SHIELD SUPPORT	ACRYLIC	4
6	B606	SPLASH SHIELD WALL	ACRYLIC	2
7	B607	POWER SUPPLY -12V/5A	--	1
8	B608	ARDUINO MEGA 2560	--	1
9	B609	FOOT PADS	--	9
10	B610	12" SERVO WIRE EXTENDER	--	8
11	B611	DIGITAL SERVO SHIELD	--	1
12	B612	NYLON STANDOFFS	--	14
13	B613	LOAD CELL SHIELD	--	1
14	B614	STEPPER MOTOR DRIVER	--	1
15	B615	KEYSWITCH	--	1
16	B616	AUXILIARY ROUTING BOARD	--	1
17	B617	TRI-STATE BUFFER CHIP	--	1
18	B618	DC MOTOR CHIP	--	1
19	B619	FUSE	--	1
20	B620	FUSE HOLDER	--	1
21	B621	BAREL JACK	--	1
22	B622	DC 12V TO 6V VOLTAGE CONVERTER	--	1

ITEM NO.	PART NUMBE R	DESCRIPTION	MATL.	QTY.
23	B623	16 GUAGE WIRE	--	18
24	B624	18 GUAGE WIRE	--	21
25	B625	WIRE NUTS	--	8
26	B626	QUICK DISCONNECT	--	4
27	B627	METAL STANDOFFS	--	4
28	B113	FASTENER COMBINATION	--	32

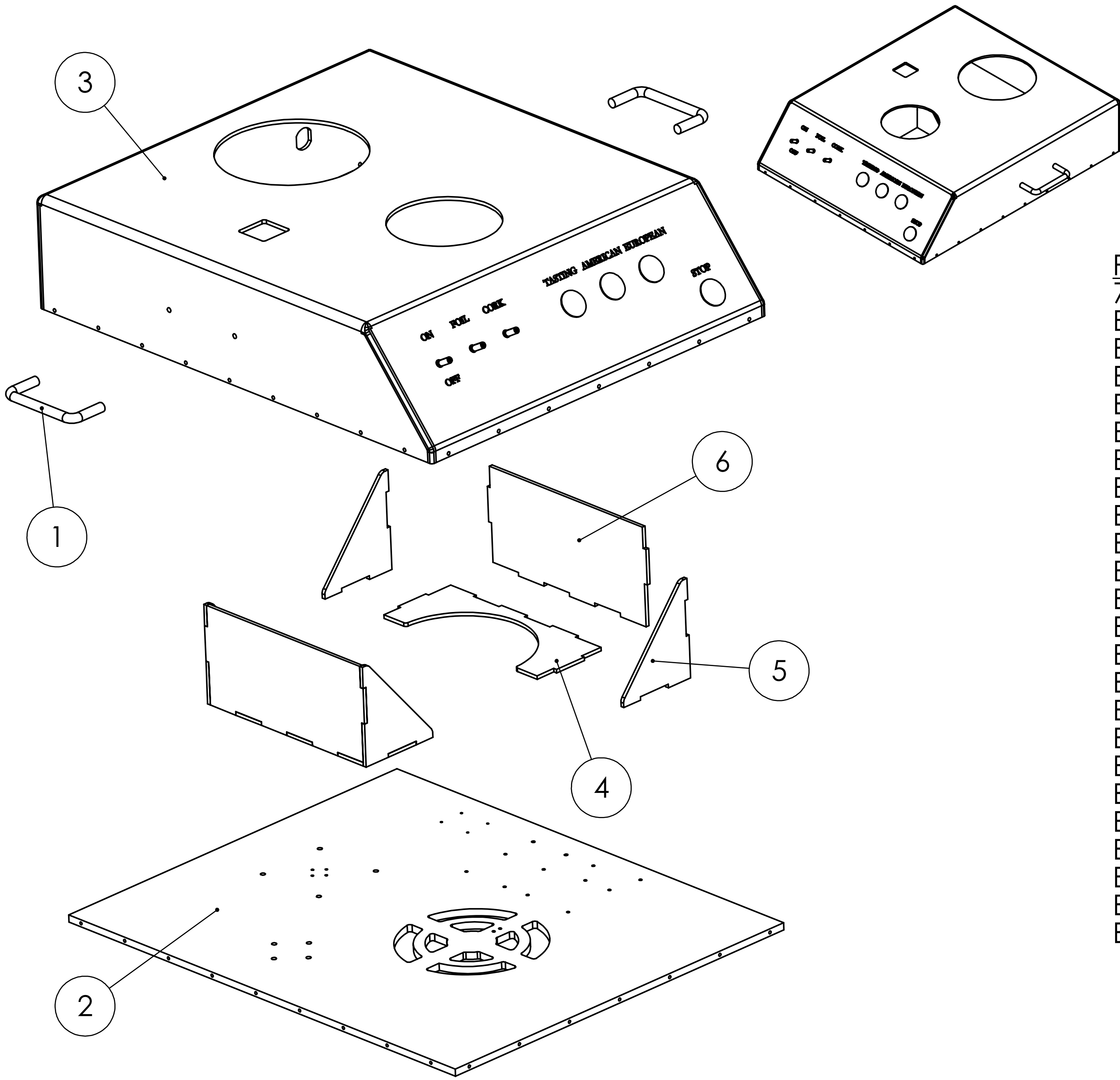
<u>PURCHASED PARTS</u>

B601 B607 B608 B609 B610 B611 B612 B613 B614 B615 B616 B617 B618
B619 B620 B621 B622 B623 B624 B625 B626 B627 B113

<u>MANUFACTURED/ MODIFIED PARTS</u>

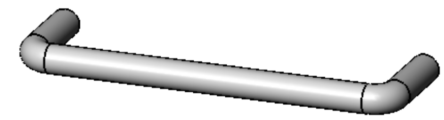
B602 B603 B604 B605 B606

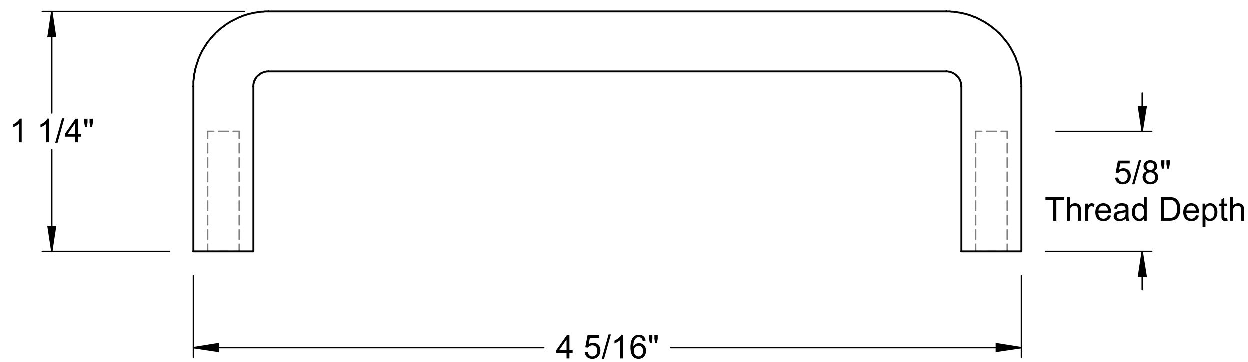
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: SEE BOM		Title:ELECTRICAL BOX/SUPPORT		Drwn. By: JULIA TRENKLE
	Dwg. #: B600	Nxt Asb: A100	Date: 5/30/2018	Scale: 1:5	Chkd. By: BERKELEY DAVIS

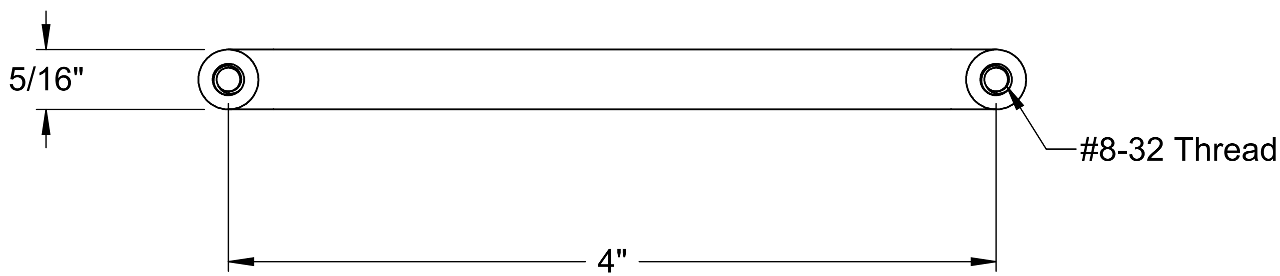


PARTS NOT SHOWN:
7 THROUGH 28
B607
B607
B608
B609
B610
B611
B612
B613
B614
B615
B616
B617
B618
B619
B620
B621
B622
B623
B624
B625
B626
B627
B613 FASTENER COMBINATION
M3 12mm SCREWS

Cal Poly Mechanical Engineering	Material: SEE BOM	Title:ELECTRICAL BOX/SUPPORT	Drwn. By: JULIA TRENKLE
SENIOR PROJECT	Dwg. #: B600 / Nxt Asb: A100	Date: 5/30/2018 / Scale: 1:5	Chkd. By: BERKELEY DAVIS

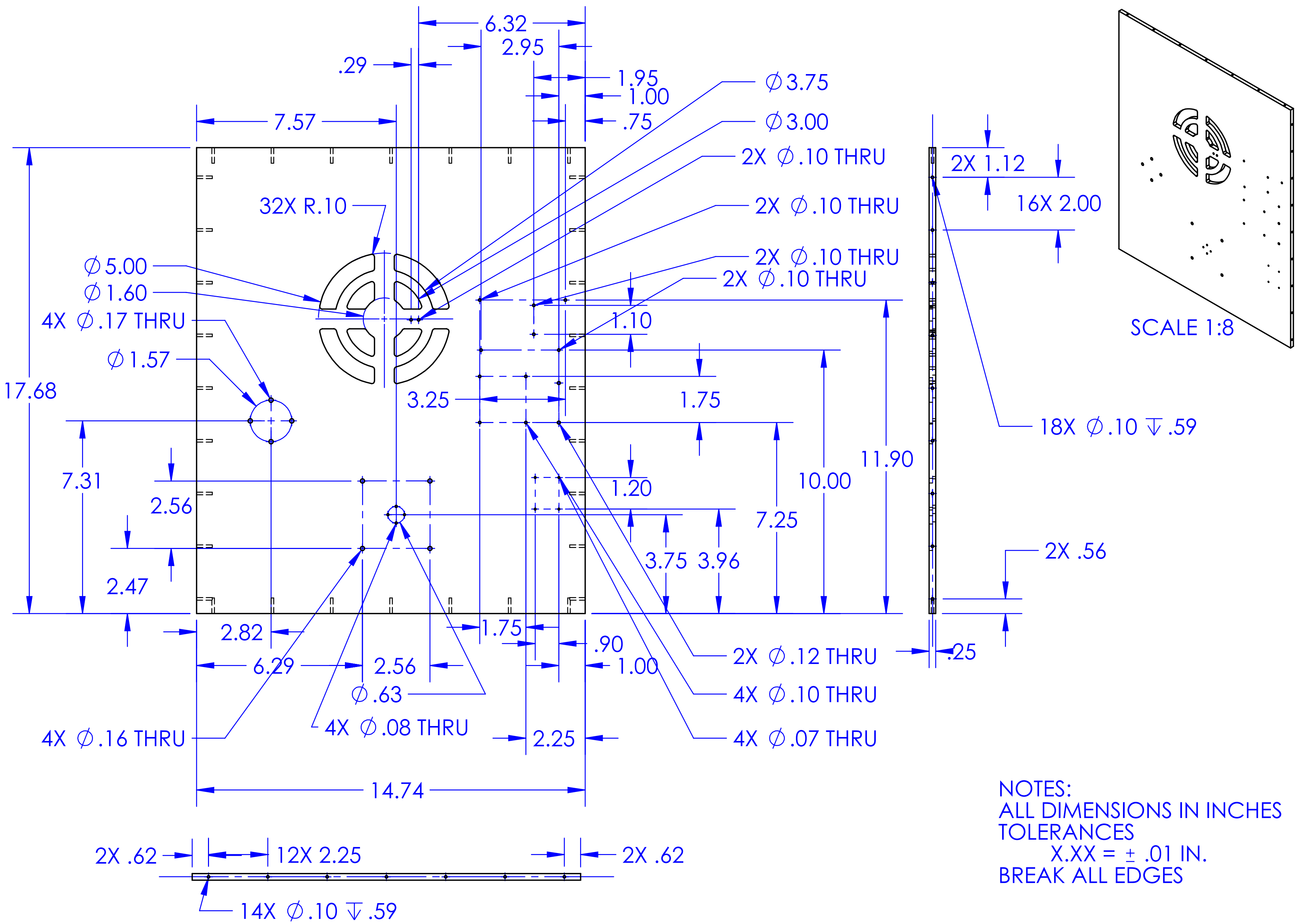






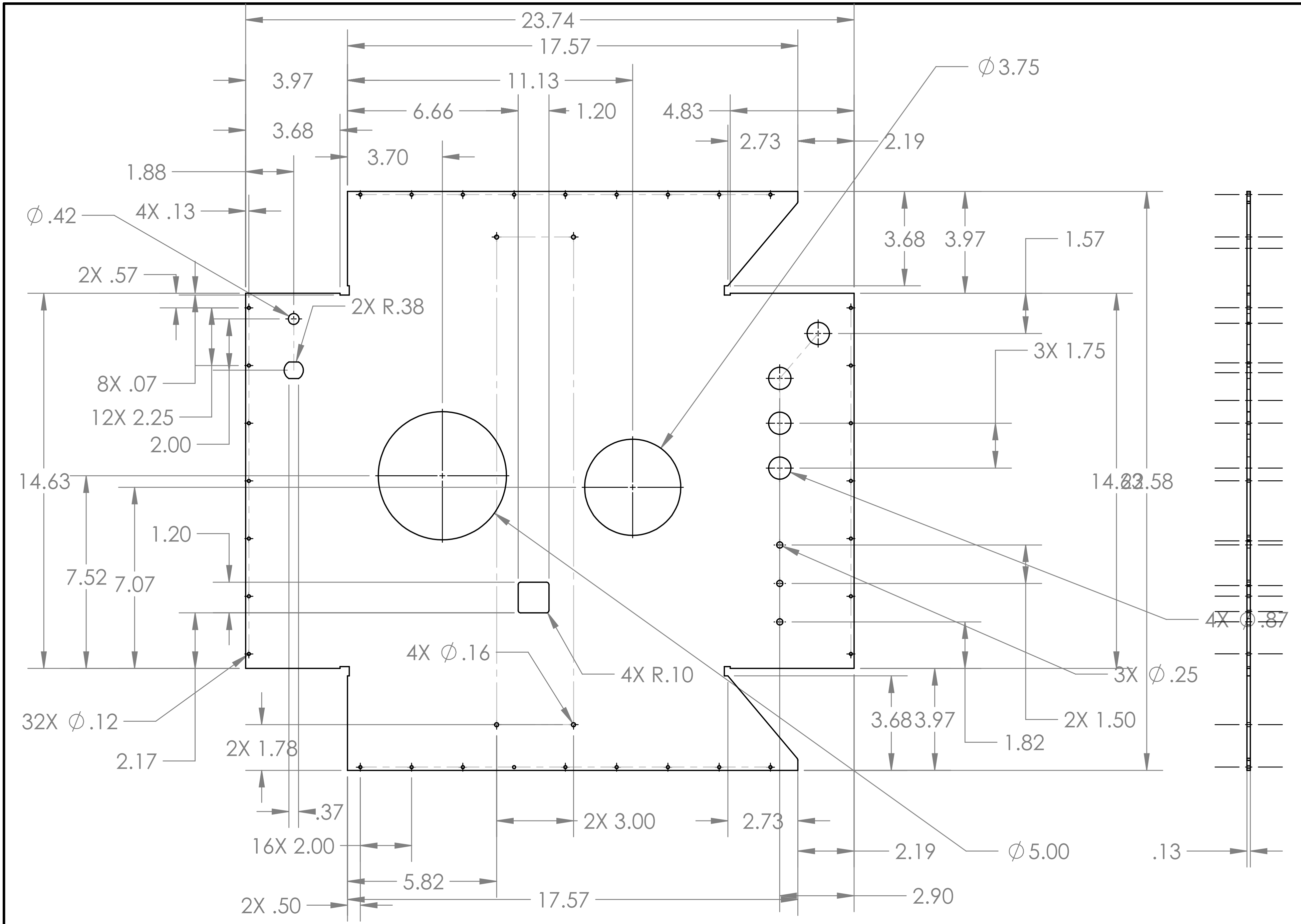
WINE OPENER P/N: B601

McMASTER-CARR® CAD	PART NUMBER	6195A51
http://www.mcmaster.com Information in this drawing is provided for reference only.	Dull Finish Type 303 Stainless Steel Pull Handle	



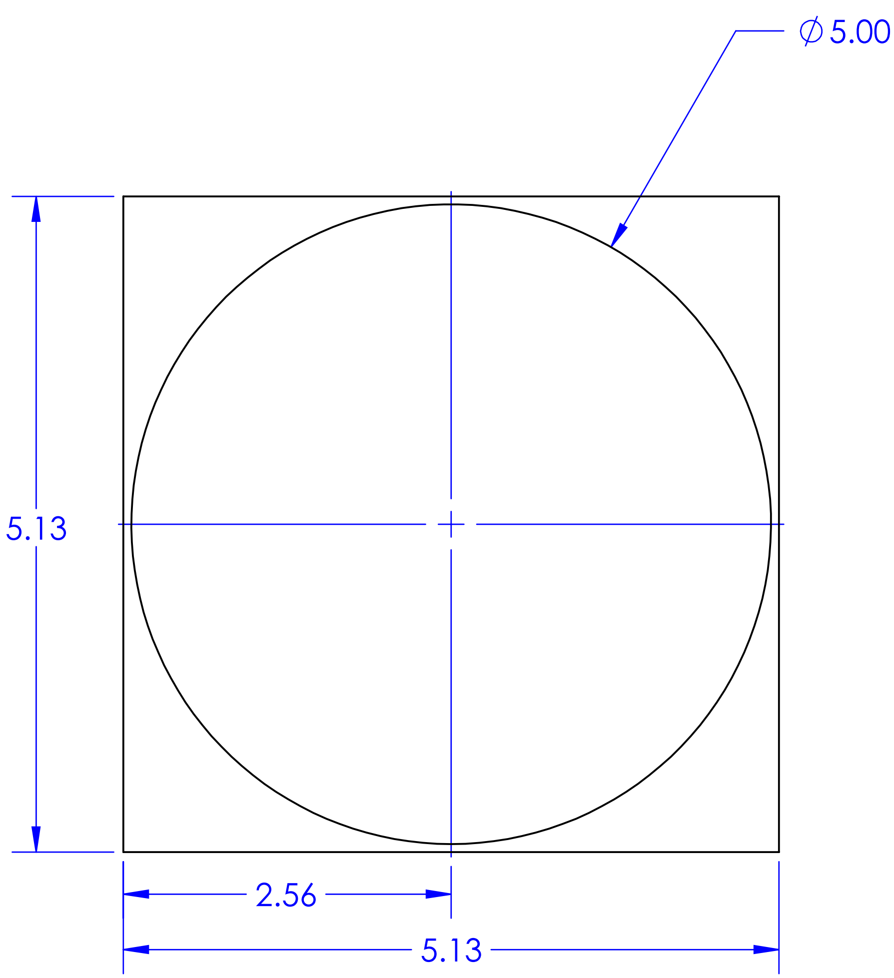
NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.
BREAK ALL EDGES

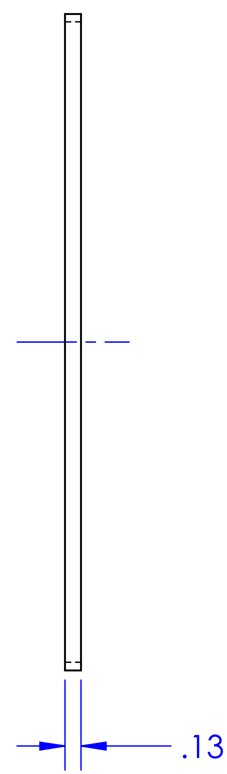
Cal Poly Mechanical Engineering SENIOR PROJECT	Material: 6061 ALUMINUM		Title: BASE PLATE	Drwn. By: BERKELEY DAVIS
	Dwg. #: B602	Nxt Asb: B600	Date:5/28/2018	Scale: 1:3	Chkd. By: JULIA TRENKLE

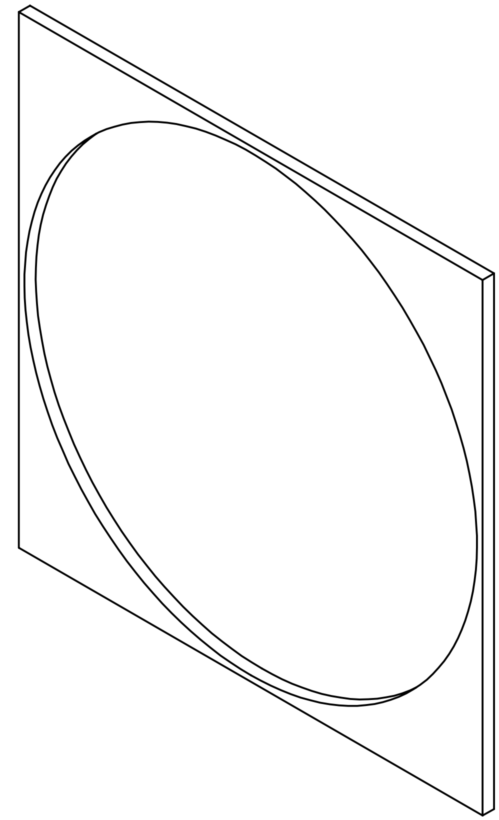


Cal Poly Mechanical Engineering ME SENIOR PROJECT	Material: ALUMINUM		Title: ELECTRONICS BOX	Drwn. By: BRETT WITTMUSS
	Dwg. #: B603	Nxt Asb: 600	Date: 5/31/2018 | Scale:1:5	Chkd. By: BERKELEY DAVIS

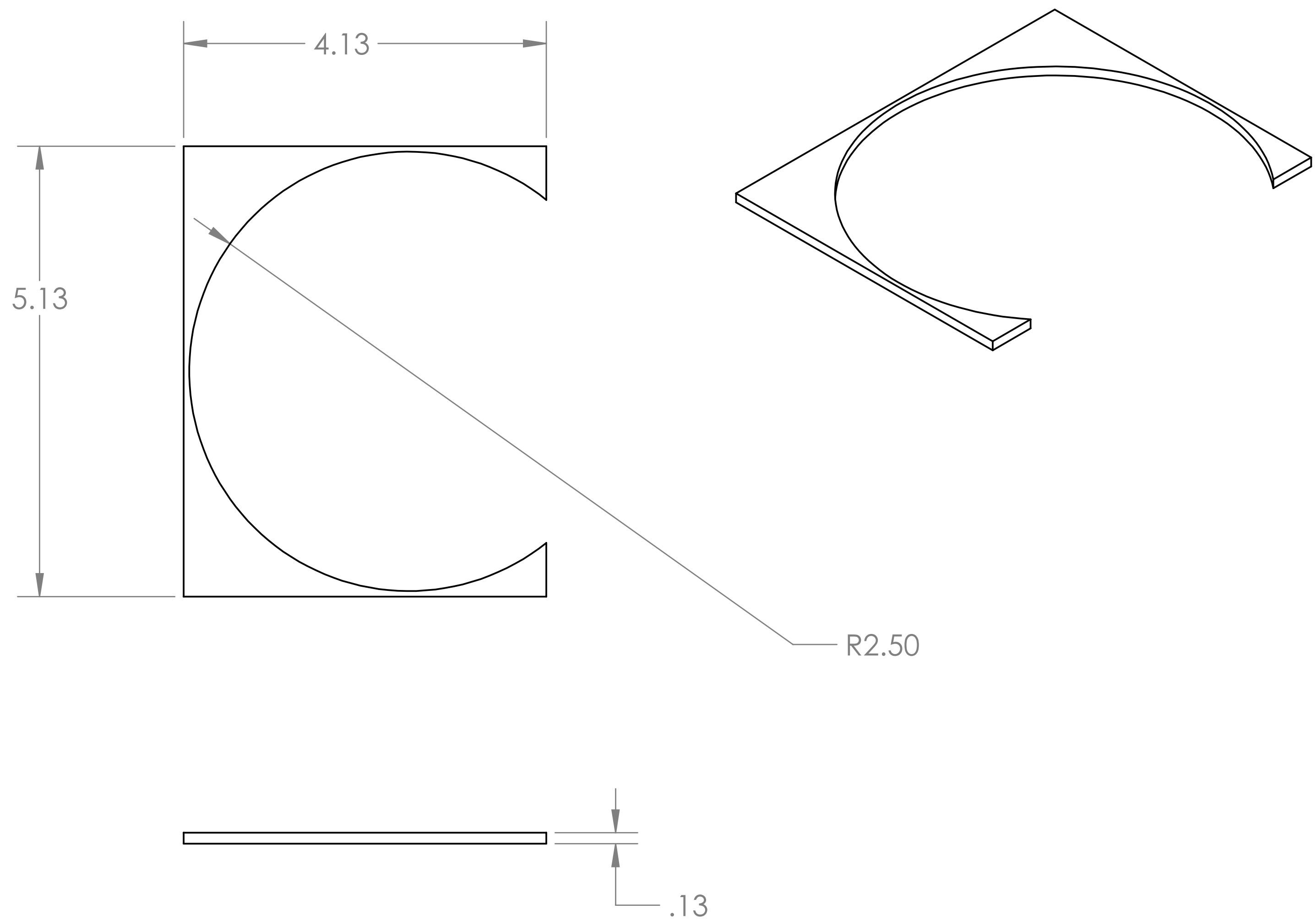
NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.





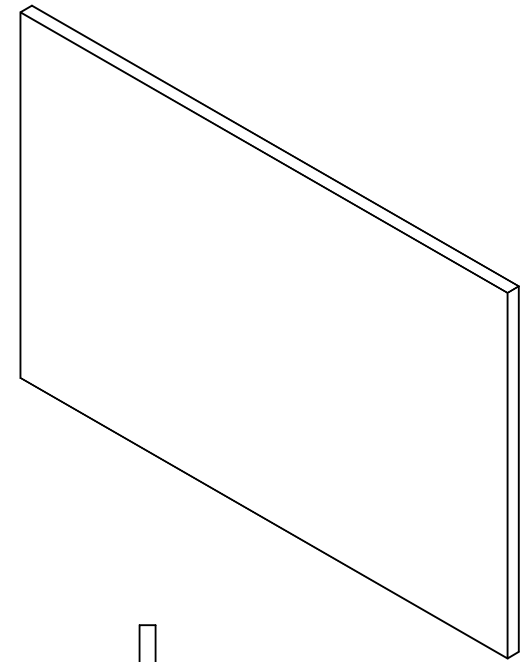


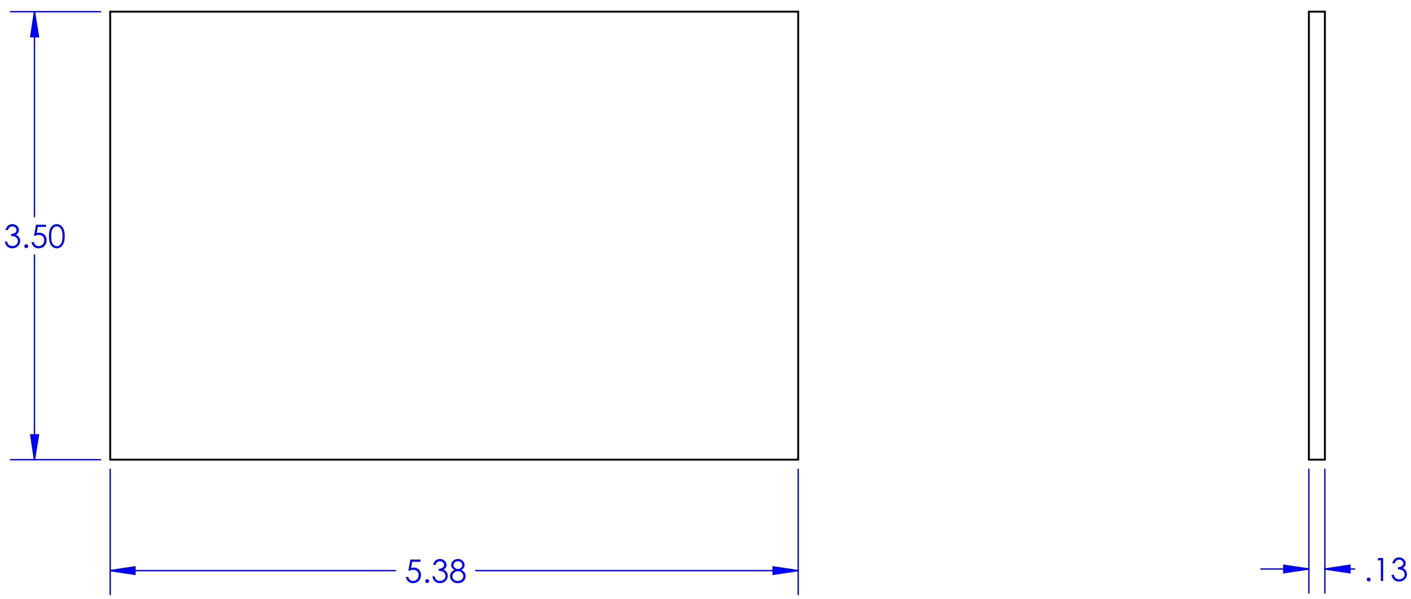
Cal Poly Mechanical Engineering	Material: ACRYLIC	Title: SPLASH SHIELD BASE	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B604 / Nxt Asb: B600	Date:5/31/2018 / Scale: 2:3	Chkd. By: BRETT WITTMUSS



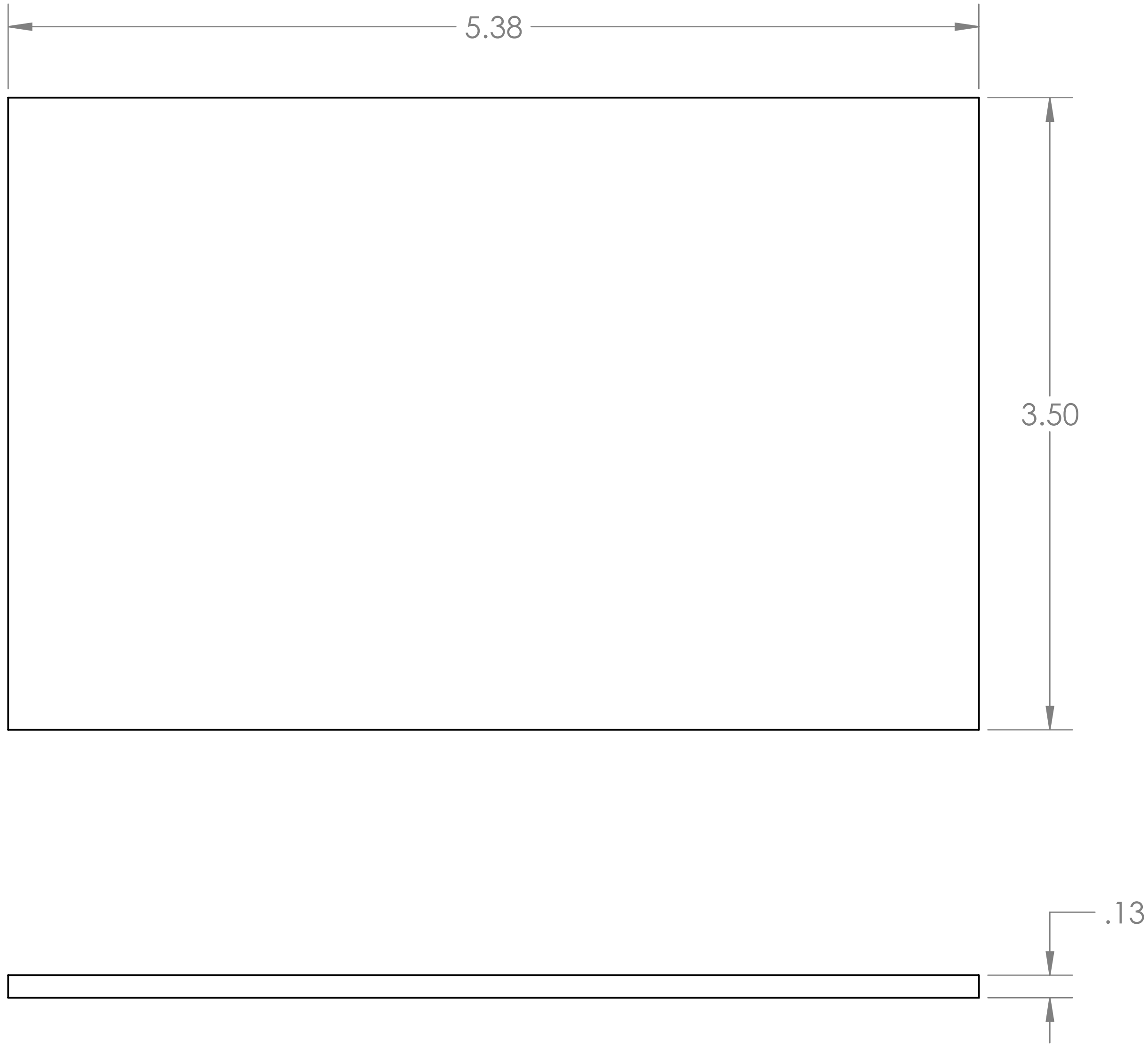
Cal Poly Mechanical Engineering	Material: Acrylic		Title: SPLASH SHIELD BASE		Drwn. By: BRETT WITTMUSS
SENIOR DESIGN	Dwg. #: B604	Nxt Asb: B600	Date: 6/1/2018	Scale: 1:2	Chkd. By: JULIA TRENKLE

NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.
BREAK ALL EDGES
CLEAN PART

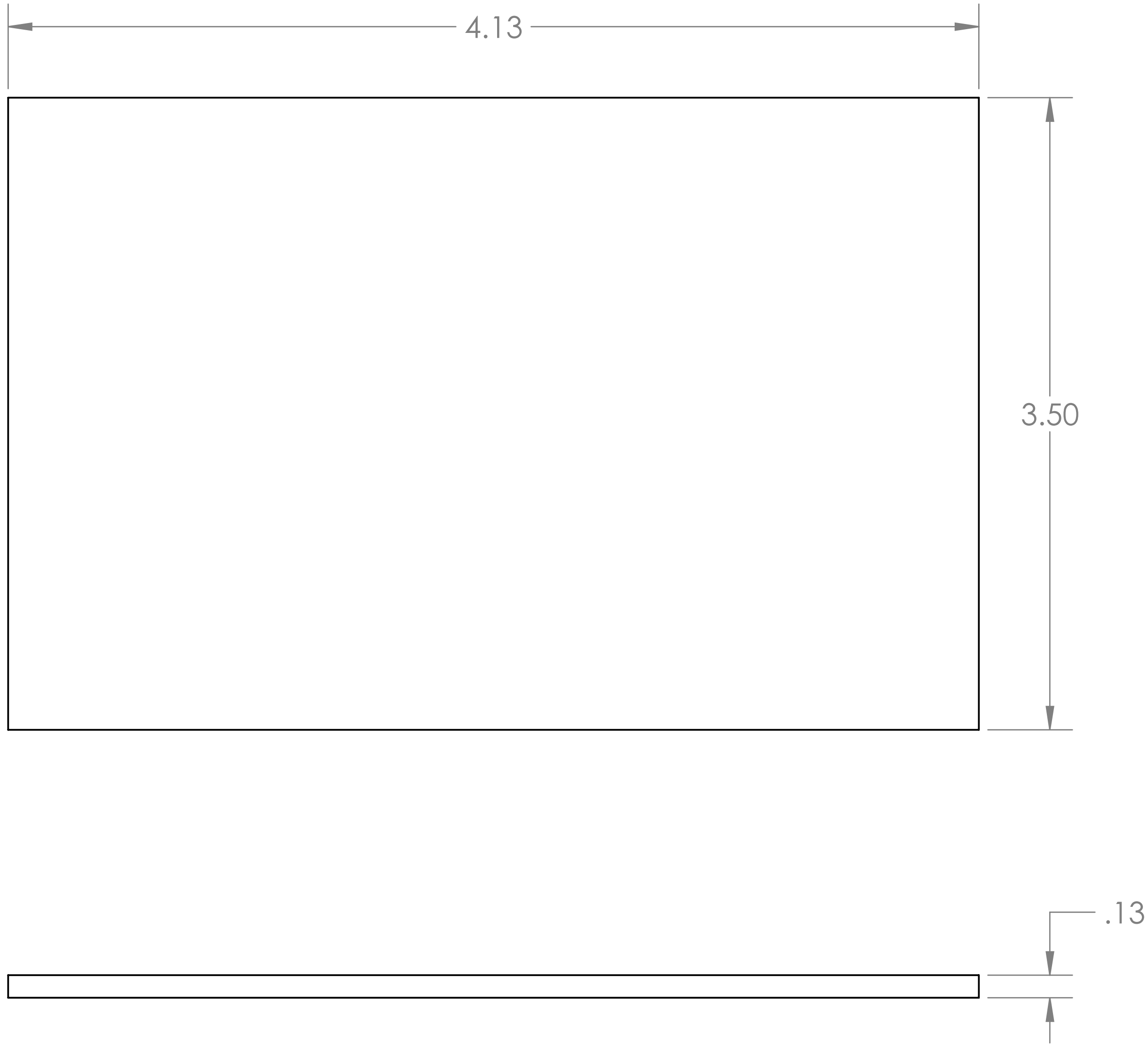




Cal Poly Mechanical Engineering	Material: ACRYLIC		Title: SPLASH SHIELD SUPPORT	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B605	Nxt Asb: B600	Date:5/31/2018	Scale: 2:3	Chkd. By: BRETT WITTMUSS

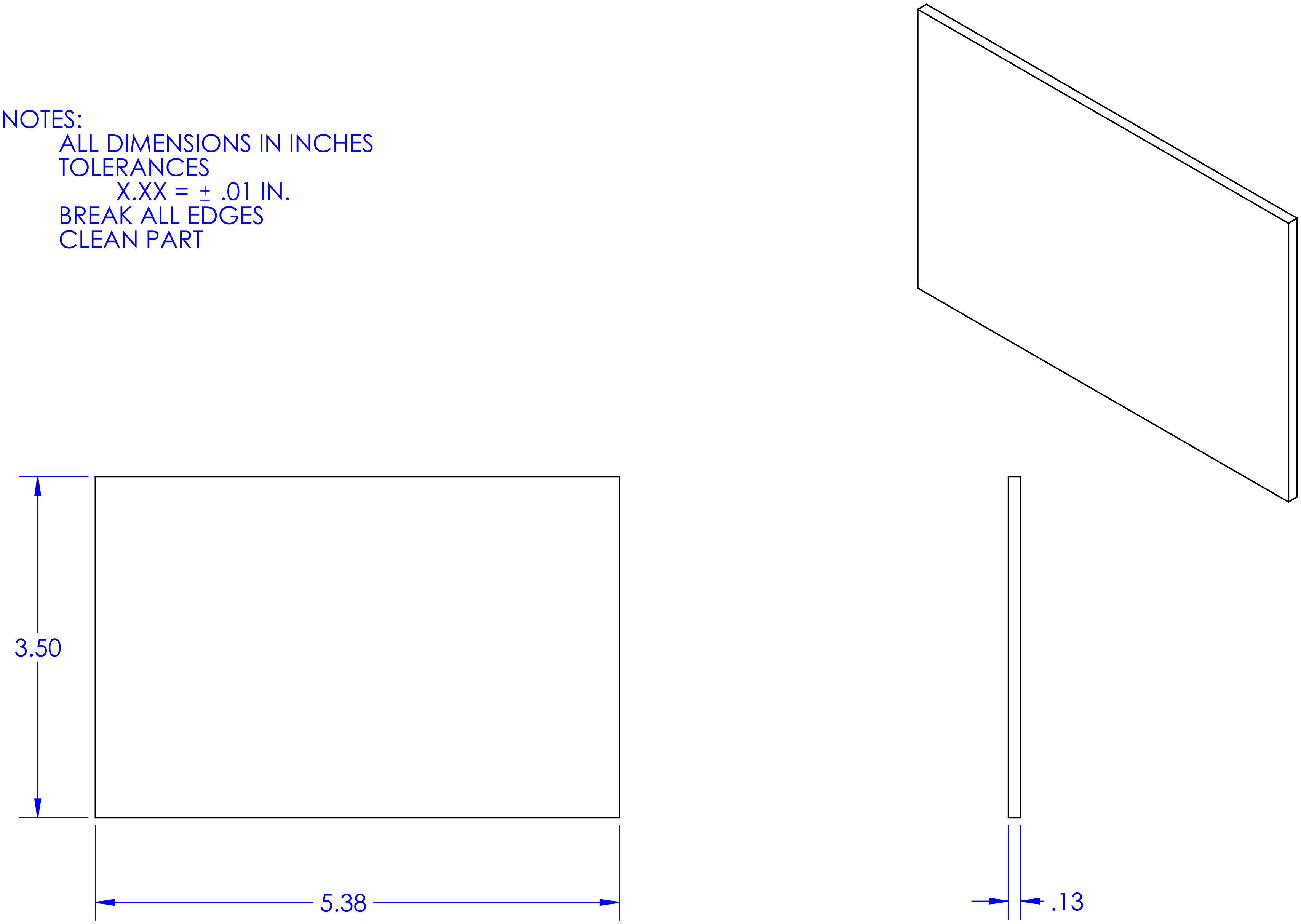


Cal Poly Mechanical Engineering	Material: Acrylic		Title: SPLASH SHIELD WALL 1	Drwn. By: BRETT WITTMUSS
SENIOR DESIGN	Dwg. #: B605	Nxt Asb: B600	Date: 6/1/2018	Scale: 1:1	Chkd. By: JULIA TRENKLE



Cal Poly Mechanical Engineering SENIOR DESIGN	Material: Acrylic		Title: SPLASH SHIELD WALL 2	Drwn. By: BRETT WITTMUSS
	Dwg. #: B606	Nxt Asb: B600	Date: 6/1/2018 / Scale: 1:1	Chkd. By: JULIA TRENKLE

NOTES:
ALL DIMENSIONS IN INCHES
TOLERANCES
X.XX = ± .01 IN.
BREAK ALL EDGES
CLEAN PART



Cal Poly Mechanical Engineering	Material: ACRYLIC	Title: SPLASH SHIELD WALL	Drwn. By: BERKELEY DAVIS
SENIOR PROJECT	Dwg. #: B606 / Nxt Asb: B600	Date:5/31/2018 / Scale: 2:3	Chkd. By: BRETT WITTMUSS

12vAdapters.com

12 Volt 10 Amp DC Power Supply Adapter, Standard

30 customer reviews | 25 answered questions

Price: $28.98 & **FREE Shipping**.Details

In Stock.

Want it Friday, June 1? Order within **1 hr 43 mins** and choose **Two-Day Shipping** at checkout. Details

Sold by EPtech and Fulfilled by Amazon. Gift-wrap available.

- World Wide Input Voltage 100-240VAC 50/60Hz
- OVP, OCP, SCP Protection (OVP: Over Voltage output Protection. OCP: Over Current output Protection. SCP: Short Circuit output Protection)
- Tested Units. In Great Working Condition.
- UpBright 30 days money back guarantee. 1 full year service warranty.
- UpBright® New AC / DC Adapter For 12 Volt 10 Amp DC Power Supply Adapter, Standard 12V 10A Power Cord Charger w/ 5.5mm x 2.5mm Tip

New (2) from $14.00 + $5.49 shipping

Product description

UpBright® New AC / DC Adapter For 12 Volt 10 Amp DC Power Supply Adapter, Standard 12V 10A Power Cord Charger w/ 5.5mm x 2.5mm Tip

Product information

Product Dimensions	8.2 x 5.3 x 2 inches
Item Weight	1.31 pounds
Shipping Weight	1.31 pounds (View shipping rates and policies)
Manufacturer	12vAdapters.com
ASIN	B00B8TRF0A
Customer Reviews	30 customer reviews 4.0 out of 5 stars
Best Sellers Rank	#19,498 in Electronics (See Top 100 in Electronics) #17,974 in Electronics > Computers & Accessories
Date first listed on Amazon	January 31, 2013

Warranty & Support

Product Warranty: For warranty information about this product, please click here

Feedback

If you are a seller for this product, would you like to **suggest updates through seller support**?
Would you like to **tell us about a lower price**?

Wine Opener P/N: B608

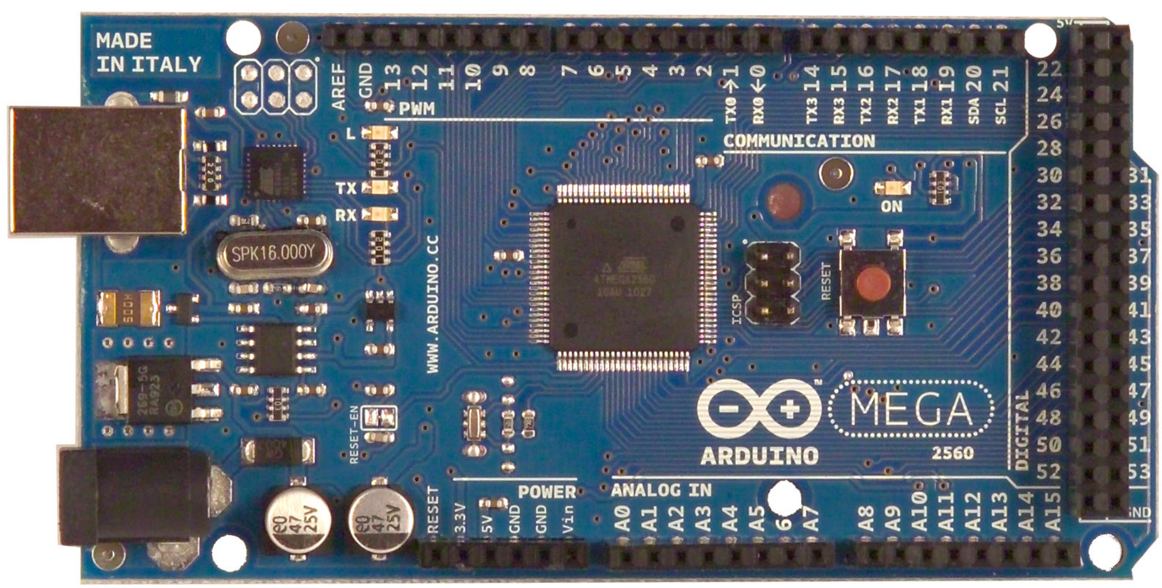
RobotShop

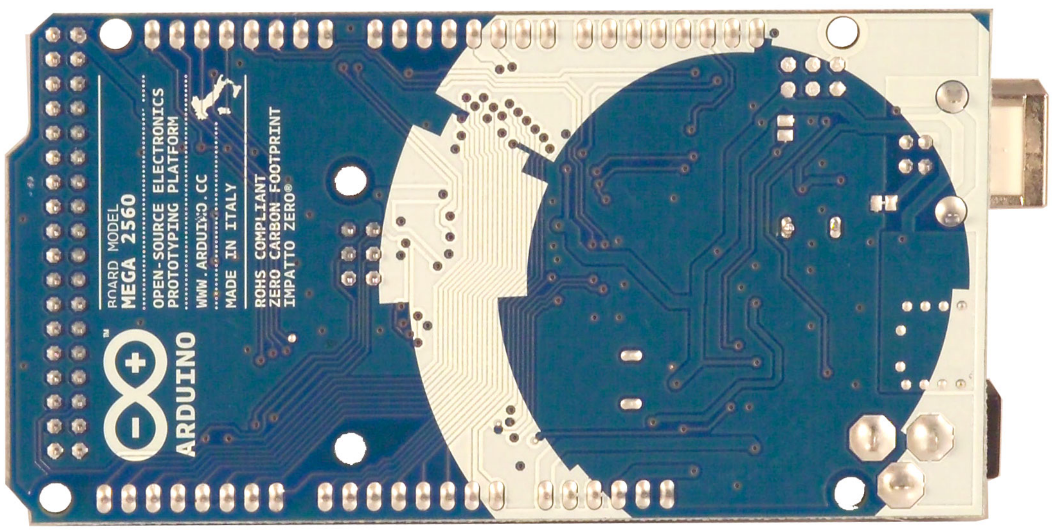
www.robotshop.com

La robotique à votre service! - Robotics at your service!

ARDUINO

Arduino Mega 2560 Datasheet





Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip

Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH

value, the LED is on, when the pin is LOW, it's off.

- **I2C: 20 (SDA) and 21 (SCL).** Support I2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the I2C pins on the Duemilanove or Diecimila.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.
The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.
The ATmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It

communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

Automatic (Software) Reset

Rather then requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.
This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened.
If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.
The Mega2560 contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

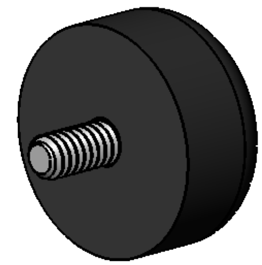
USB Overcurrent Protection

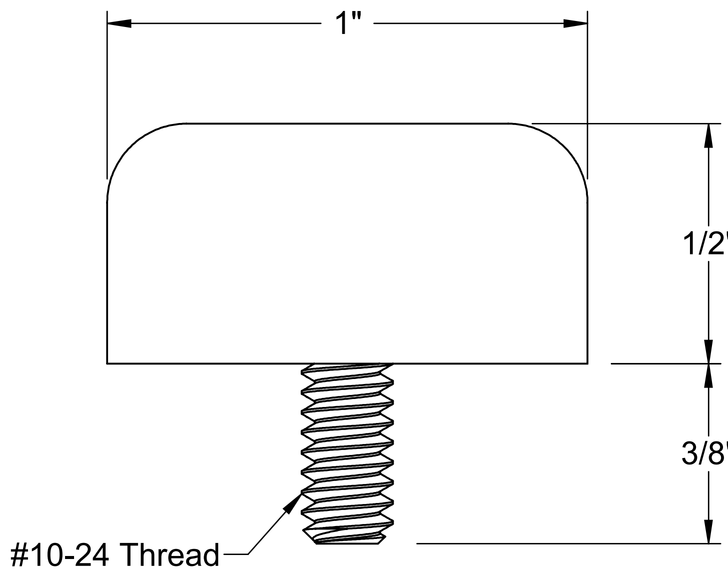
The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

The maximum length and width of the Mega2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

The Mega2560 is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the Mega2560 and Duemilanove / Diecimila. *Please note that I_2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).*





WINE OPENER P/N: B609

McMASTER-CARR® CAD	PART NUMBER	9541K3
http://www.mcmaster.com © 2013 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Bumper with Threaded Stud	

SEA-02 Servo Extender Cable - 12"

Product Code : RB-Onl-03 by Lynxmotion

(3) Add my review

In stock

- Servo Extender Cable - 12"
- Works with RC receivers or servo controllers

About this product

Description Specifications Useful Links Supplier Product Code Reviews

Description

- Servo Extender Cable - 12"
- Works with RC receivers or servo controllers

The **SEA-02 Servo Extender Cable - 12"** works with RC receivers or servo controllers. Easily extends the distance a servo can be from the control electronics. Remove the pins and it becomes a female to female cable for the PING.

Useful Links

Website

• Lynxmotion User and Assembly Guides

Specifications

- Weight: 0.01 lbs

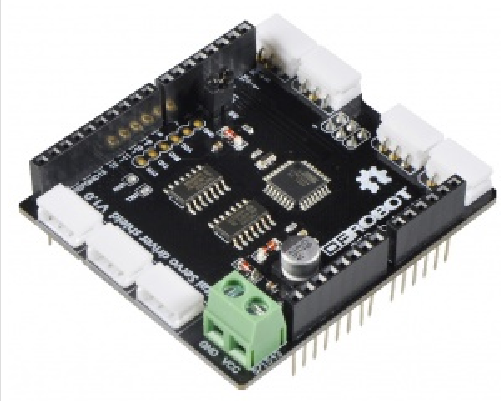
Supplier Product Code

SEA-02

Digital Servo Shield for Arduino SKU:DRI0027

Wine Opener P/N: B611

Contents



(https://www.dfrobot.com/product-958.html)
Digital Servo Shield for Ardhuino_DRI0027 (https://www.dfrobot.com/product-958.html)

Introduction

This board Integrates a half duplex circuit inside. That means the transmit wire from your UART is connected to all of the AX-12 servos. Hence: when you send a command over the wire then all of the servos will hear it - but because the message contains the destination servo ID then only one servo, matching that ID number, will process it.

Because of the servo can be linked by serial bus, which can connect up to 200+ servos. Each unit can feedback its position, rotation velocity, torque, current, motor temperature and so on.It can do rotating all round, and the velocity can be controlled, just act as a gear motor. This feature enables it to work as a motor of wheeled robots (https://www.dfrobot.com/category-111.html), or tracked robots.

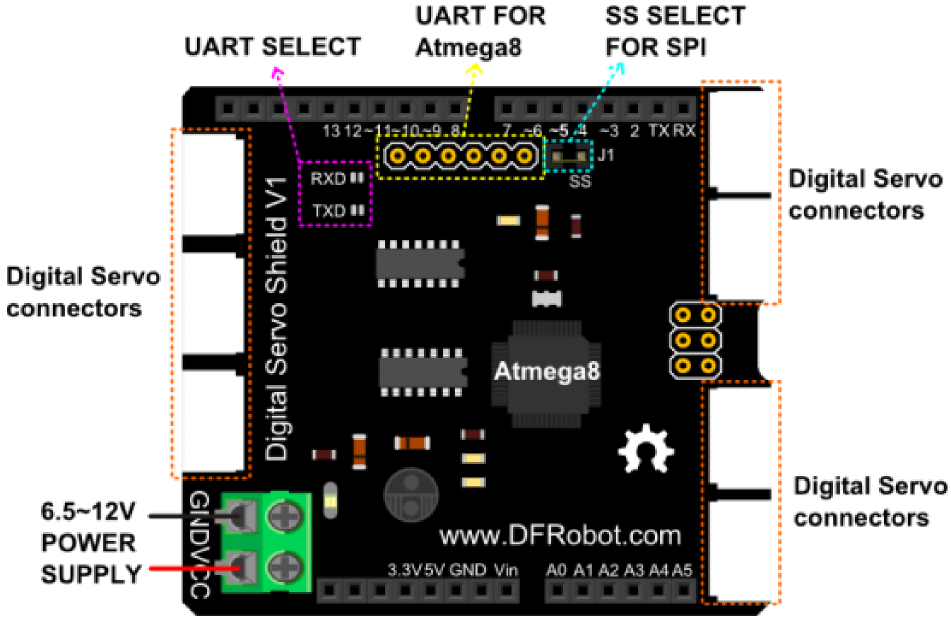
Application

- Education
- Robot Arm
- Humanoid Robot
- Hexapod Robot
- Any other servo driven application

Specification

- MCU:Atmega8
- Power Supply:6.5-12V
- Compatible with Arduino R3
- SPI interface with Arduino(Digital 10,11,12,13)
- Friendly using for the primary user
- UART interface for deeper development
- 7 channels for servo connecting
- A half duplex circuit inside
- Board surface:Immersion Gold
- Size:59x53mm

Pin Out

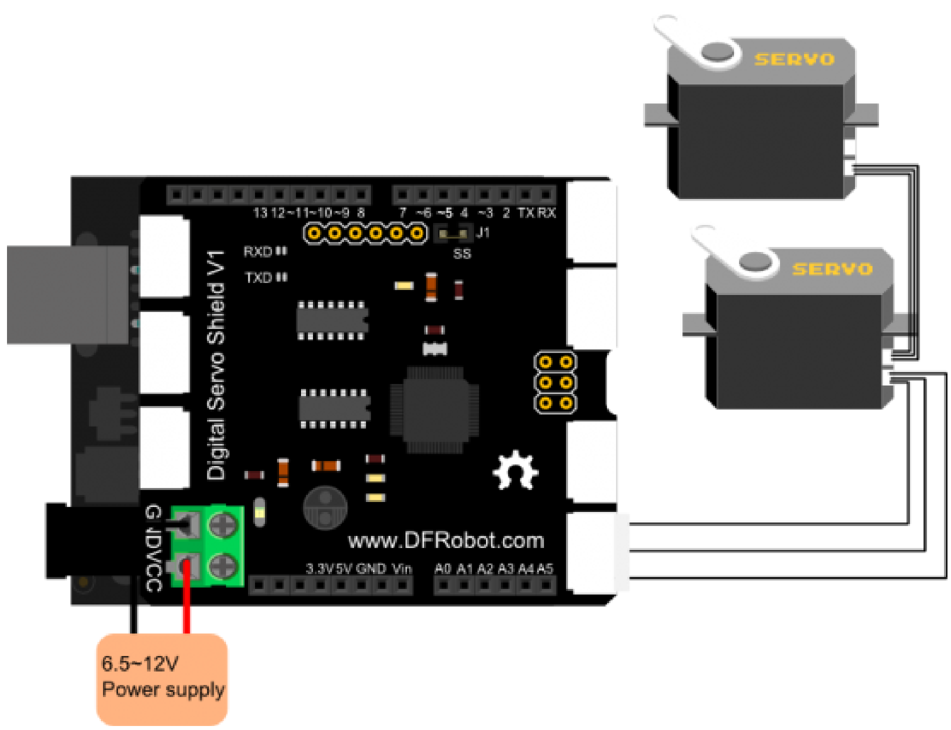


(/wiki/index.php/File:DRI0027_Pinout_update2.png)

More Details

- **POWER SUPPLY:** 6.5~12V power supply for servos & the whole system.
- **UART SELECT:** UART is already shorted by solder. When you use the UART FOR ATmega8 please remove solder off. Visit Forum for more details (http://www.dfrobot.com/forum/viewtopic.php?f=8&t=1781&p=8424#p8445).
- **UART FOR ATmega8:**This UART interface is for deeper development of the shield.You can program the atmega8 on the board with FTDI (http://www.dfrobot.com/index.php?route=product/product&filter_name=ftdi&product_id=147#.UaLcBLUwfN4).Board choose "Arduino Optiboot8 "
- **SS SELECT FOR SPI:**Digital pin 10 in default.If you want to use other digital pins,please remove the jumper cap and connect the ss header to other Arduino digital pin.

Connection Diagram

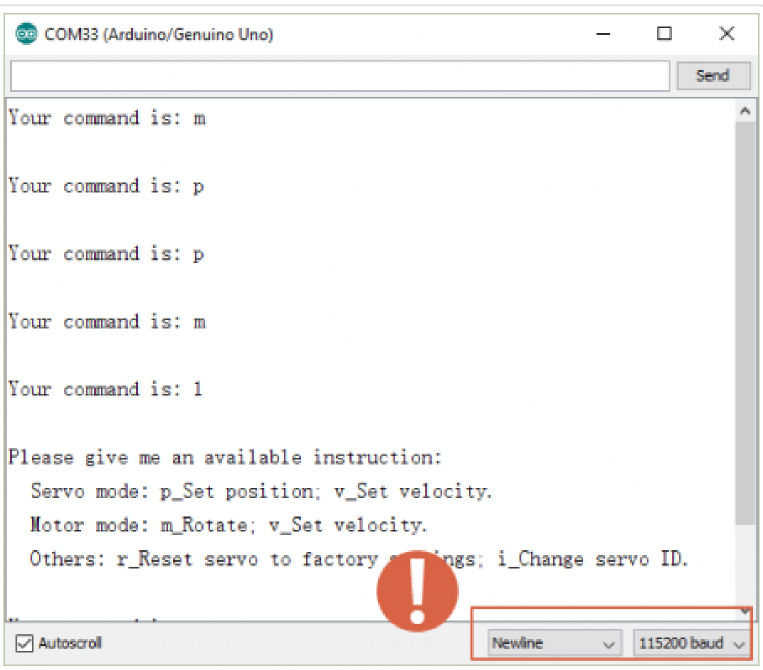


(/wiki/index.php/File:DRI0027_Diagram.png)

Sample Code

```
/*
 # This Sample code is to test the Digital Servo Shield.
 # Editor : Leff
 # Date   : 2016-1-19
 # Ver    : 1.1
 # Product: Digital Servo Shield for Arduino

 # Hardwares:
 1. Arduino UNO
 2. Digital Servo Shield for Arduino
 3. Digital Servos( Compatible with AX-12,CDS55xx...etc)
 4. Power supply:6.5 - 12V

 # How to use:
 If you don't know your Servo ID number, please
 1. Open the serial monitor, and choose NewLine,115200
 2. Send command:'d',when it's finished, please close the monitor and re-open it
 3. Send the command according to the function //controlServo()//
*/

#include <SPI.h>
#include <ServoCds55.h>
ServoCds55 myservo;

int servoNum = 1;
char inputCommand ;         // a string to hold incoming data
boolean inputComplete = false;

void setup () {
  Serial.begin (115200);
  myservo.begin ();
}

void loop () {
  serialEvent();
  if (inputComplete) {
    Serial.print("Your command is: "); Serial.println(inputCommand); Serial.println("");
    controlServo(inputCommand);
    // clear the command:
    inputCommand = 0;
    inputComplete = false;
  }
}

void serialEvent() {
  while (Serial.available()) {
    char inChar = (char)Serial.read();
    if (inChar == '\n') {
      inputComplete = true;
      break;
    }
    inputCommand += inChar;
  }
}

void controlServo(char val) {
  switch (val) {
    case 'p':
      myservo.write(servoNum, 300); //ID:1  Pos:300  velocity:150
      delay(3000);
```

```
      myservo.write(servoNum, 0); //ID:1  Pos:0  velocity:150
      break;
    case 'v':
      myservo.setVelocity(200);// set velocity to 100(range:0-300) in Servo mode
      break;
    case 'm':
      myservo.rotate(servoNum, 150); //   Anti CW    ID:1  Velocity: 150_middle velocity  300_max
      delay(2000);
      myservo.rotate(servoNum, -150); //  CW     ID:1  Velocity: -150_middle velocity  -300_max
      delay(2000);
      myservo.rotate(servoNum, 0); //Stop
      myservo.Reset(servoNum);    //Only Dynamixel AX need this instruction while changing working mode
      //CDS55xx don't need this, it can switch freely between its working mode
      break;
    case 'r':
      myservo.Reset(servoNum);//Restore ID2 servo to factory Settings ( ID:1  Baud rate:1000000)
      break;
    //        case 'i':
    //        myservo.SetID(2,1);//ID:1   newID:2
    //        break;
    case 'd':  //Reset servo to ID>>servoNum. If you don't know your Servo ID, please send "d".
      Serial.print("Please wait..");
      for (int buf = 0; buf < 255; buf++) {
        myservo.SetID(buf, servoNum);
        if (buf % 50 == 0) Serial.print(".");
      }
      delay(2000);
      Serial.println("");   Serial.println("Please close the monitor and re-open it to play your servo! ");
      break;
    default:
      Serial.println("Please give me an available instruction:");
      Serial.println("  Servo mode: p_Set position; v_Set velocity.");
      Serial.println("  Motor mode: m_Rotate; v_Set velocity.");
      Serial.println("  Others: r_Reset servo to factory settings; i_Change servo ID."); Serial.println("");
  }
}
```



(/wiki/index.php/File:DRI0027_Serial_monitor_command.png)

Send command after uploading.

(http://www.dfrobot.com/) Shop from **Smart Arduino Digital Servo Shield for Dynamixel AX** (https://www.dfrobot.com/product-958.html) or **DFRobot Distributor**. (http://www.dfrobot.com/index.php?route=information/distributorslogo)

Category: DFRobot (https://www.dfrobot.com/) > **Arduino** (https://www.dfrobot.com/category-35.html) > Arduino Shields (https://www.dfrobot.com/category-124.html)

Categories (/wiki/index.php/Special:Categories): Product Manual (/wiki/index.php/Category:Product_Manual) | DRI Series (/wiki/index.php/Category:DRI_Series) | Shield (/wiki/index.php?title=Category:Shield&action=edit&redlink=1)

Wine Opener P/N: B612

The Future of Analog IC Technology®

MP6500

35V, 2.5A, Stepper Motor Driver

DESCRIPTION

The MP6500 is a stepper motor driver with a built-in translator and current regulation. Current sensing is internal and requires no external sense resistors. High integration and a small package size make the MP6500 a space-saving and cost-effective solution for bipolar stepper motor drives.

The MP6500 operates from a supply voltage of up to 35V and can deliver motor currents up to 2.5A (depending on PCB design and thermal conditions). The MP6500 can operate a bipolar stepper motor in full-, half-, quarter-, or eighth-step modes. Internal safety features include over-current protection (OCP), input over-voltage protection (OVP), under-voltage lockout (UVLO), and thermal shutdown.

The MP6500 is available in QFN-24 (5mmx5mm) and TSSOP-28 EP packages.

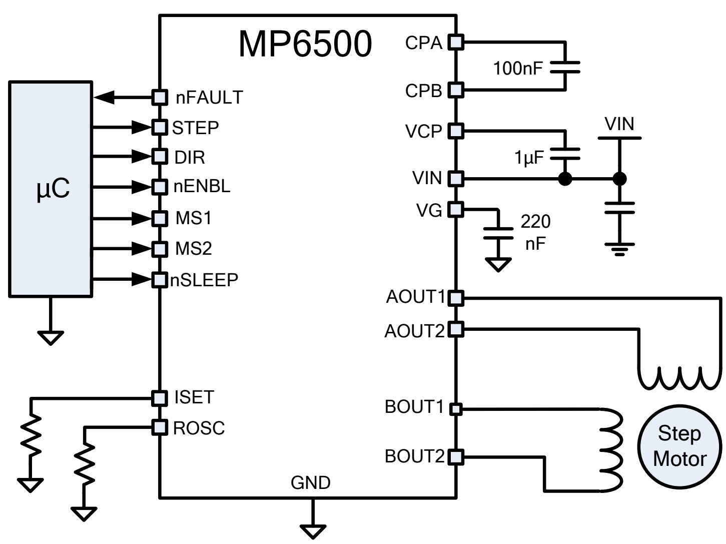
FEATURES

- Wide 4.5V to 35V Input Voltage Range
- Two Internal Full-Bridge Drivers
- Internal Current Sensing and Regulation
- Low On Resistance (HS: 195mΩ, LS: 170mΩ)
- No Control Power Supply Required
- Simple Logic Interface
- 3.3V and 5V Compatible Logic Supply
- Step Modes from Full-Step to Eighth-Step
- 2.5A Output Current
- Automatic Current Decay
- Over-Current Protection (OCP)
- Input Over-Voltage Protection (OVP)
- Thermal Shutdown and Under-Voltage Lockout (UVLO) Protection
- Fault Indication Output
- Available in QFN-24 (5mmx5mm) and Thermally Enhanced TSSOP-28 Packages

APPLICATIONS

- Bipolar Stepper Motors
- Printers

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking
MP6500GF*	TSSOP-28 EP	*See Below*
MP6500GU**	QFN-24 (5mmx5mm)	*See Below*

* For Tape & Reel, add suffix –Z (e.g. MP6500GF–Z)
** For Tape & Reel, add suffix –Z (e.g. MP6500GU–Z)

TOP MARKING

MPSYYWW
MP6500
LLLLLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
MP6500: Part number
LLLLLLLLL: Lot number

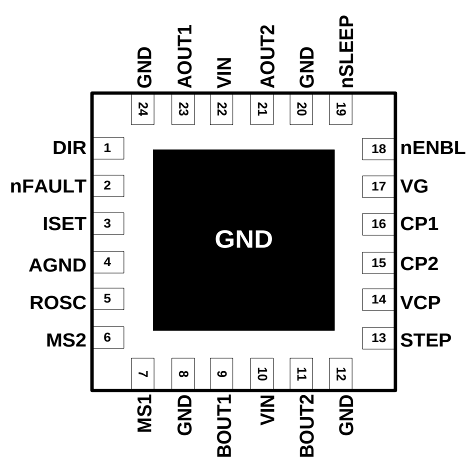
TOP MARKING

MPSYYWW
MP6500
LLLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
MP6500: Part number
LLLLLLL: Lot number

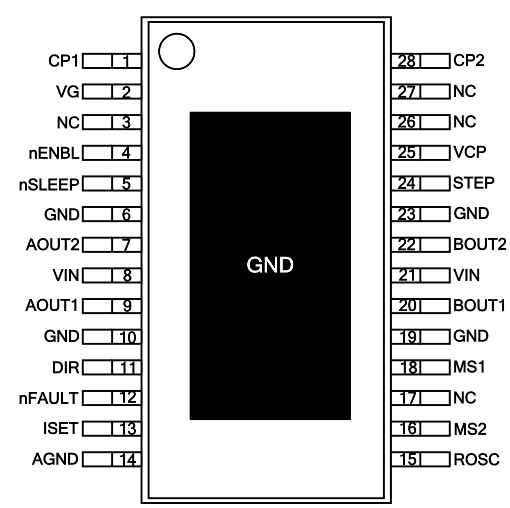
PACKAGE REFERENCE

TOP VIEW



QFN-24 (5mmx5mm)

TOP VIEW



TSSOP-28 EP

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (VIN) .... -0.3V to 40V
xOUTx voltage ($V_{A/BOUT1/2}$) .... -0.7V to 40V
VCP, CPB .... VIN to VIN + 6.5V
All other pins to AGND .... -0.3V to 6.5V
ESD rating (HBD) 2kV
Continuous power dissipation (T_A = +25°C) (2)
QFN 3.5W
TSSOP 3.9W
Storage temperature .... -55°C to +150°C
Junction temperature .... +150°C
Lead temperature (solder) .... +260°C

Recommended Operating Conditions (3)

Supply voltage (VIN) .... 4.5V to 35V
Output current ($I_{A,BOUT}$) .... ±2.5A
Operating junction temp. (T_J) .. -40°C to +125°C

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
QFN-25 (5mmx5mm)	36	8	°C/W
TSSOP-28 EP	32	6	°C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

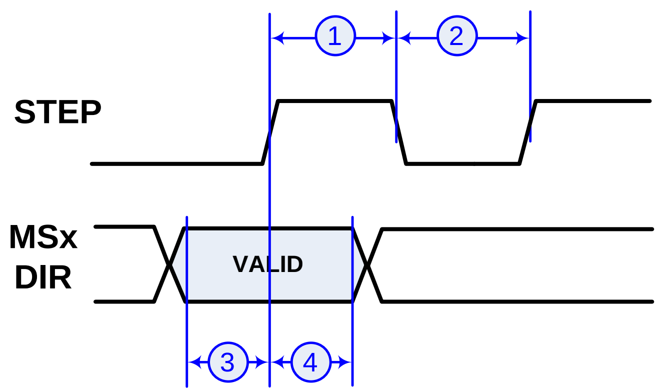
VIN = 24V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Power Supply						
Input supply voltage	V_{IN}		4.5	24	35	V
Quiescent current	I_Q	VIN = 24V, nENBL = 0, nSLEEP = 1, with no load		1.5	5	mA
	I_{SLEEP}	VIN = 24V, nSLEEP = 0			1	µA
Internal MOSFETs						
Output on resistance	R_{HS}	VIN = 24V, I_{OUT} = 1A, T_J = 25°C		0.195	0.22	Ω
		VIN = 24V, I_{OUT} = 1A, T_J = 85°C		0.25		Ω
	R_{LS}	VIN = 24V, I_{OUT} = 1A, T_J = 25°C		0.17	0.21	Ω
		VIN = 24V, I_{OUT} = 1A, T_J = 85°C		0.25		Ω
Body diode forward voltage	V_F	I_{OUT} = 1.5A			1.1	V
Control Logic						
Input logic low threshold	V_{IL}				0.8	V
Input logic high threshold	V_{IH}		2.1			V
Logic input current	$I_{IN(H)}$	V_{IH} = 5V			20	µA
	$I_{IN(L)}$	V_{IL} = 0.8V			5	µA
Internal pull-down resistance	R_{PD}			500		kΩ
Home nFAULT Outputs (Open-Drain Outputs)						
Output low voltage	V_{OL}	I_O = 5mA			0.5	V
Output high leakage current	I_{OH}	V_O = 3.3V			1	µA
Protection Circuit						
UVLO rising threshold	V_{IN_RISE}			3.4	4.5	V
Input OVP threshold	V_{OVP}		36	37.5	38.5	V
Input OVP hysteresis	ΔV_{OVP}			1900		mV
Over-current trip level	I_{OCP1}	Sinking	3.5	6	8.5	A
	I_{OCP2}	Sourcing	3.5	6	8.5	A
Over-current deglitch time	t_{OCP}			1		µs
Thermal shutdown	T_{TSD}			165		°C
Thermal shutdown hysteresis	ΔT_{TSD}			15		°C
Current Regulation						
Constant off time	t_{OFF}	R_{osc} = 200kΩ	20	23	26	µs
Peak current regulation level	I_{PEAK}	R_{ISET} = 78kΩ	0.95	1.0	1.05	A
ISET voltage	V_{ISET}		0.8	0.9	1	V
ISET current ratio	A_{ISET}	I_{ISET}/I_{OUT}	10	11.539	13	µA/A
Blanking time	t_{BLANK}			2		µs
Current trip accuracy	ΔI_{TRIP}	R_{ISET} = 78kΩ, 71% - 100%	-5		5	%
		R_{ISET} = 78kΩ, 38% - 67%	-9		9	%
		R_{ISET} = 78kΩ, <34%	-12		12	%

TIMING CHARACTERISTICS

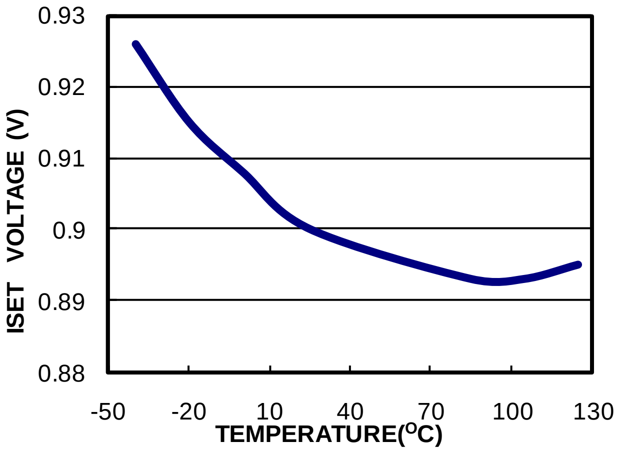
VIN = 24V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
STEP high time	t1		1			µs
STEP low time	t2		1			µs
Setup time MSx, DIR to STEP rising	t3		200			ns
Hold time STEP rising to MSx, DIR change	t4		200			ns

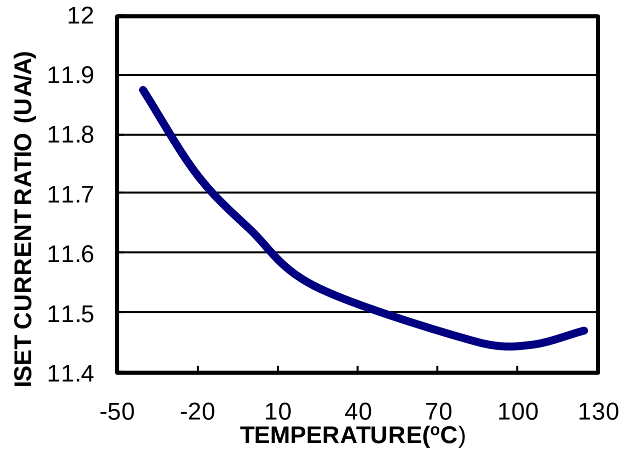


TYPICAL CHARACTERISTICS

ISET Voltage vs. Temperature

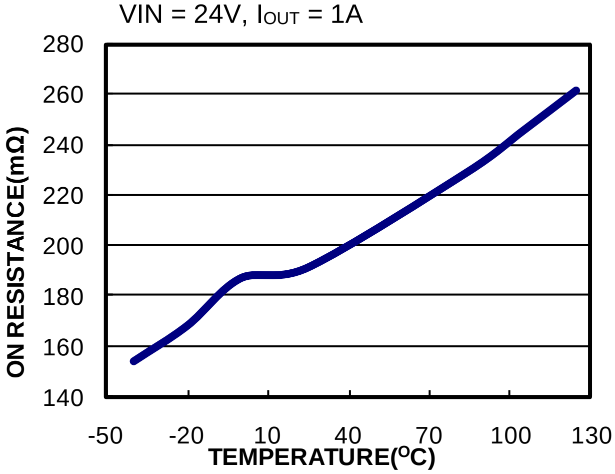


ISET Current Ratio vs. Temperature



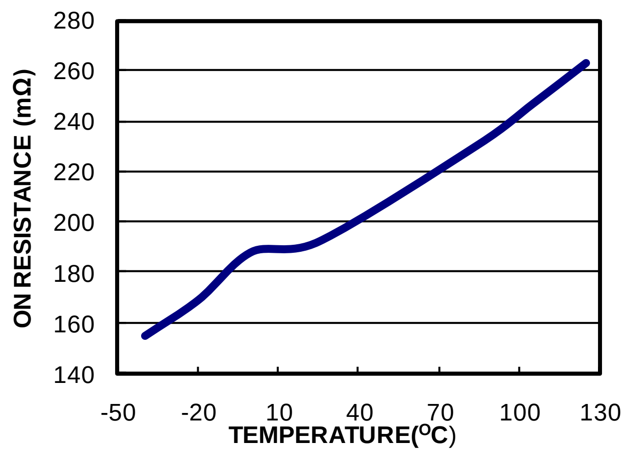
Bridge A HS On Resistance vs. Temperature

VIN = 24V, I_{OUT} = 1A



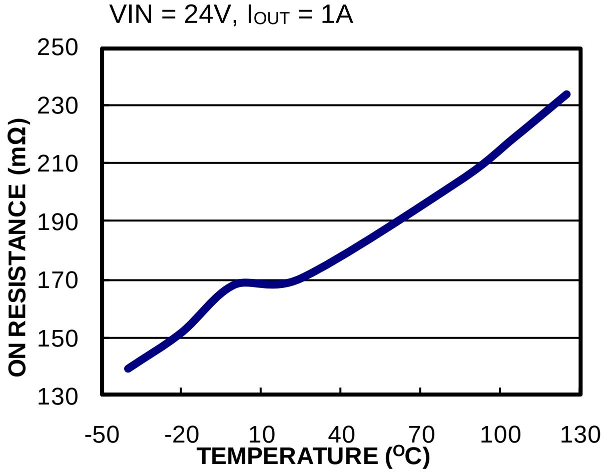
Bridge B HS On Resistance vs. Temperature

VIN = 24V, I_{OUT} = 1A



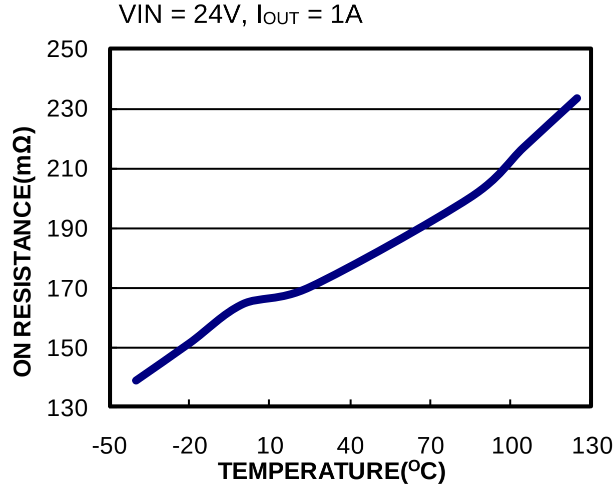
Bridge A LS On Resistance vs. Temperature

VIN = 24V, I_{OUT} = 1A



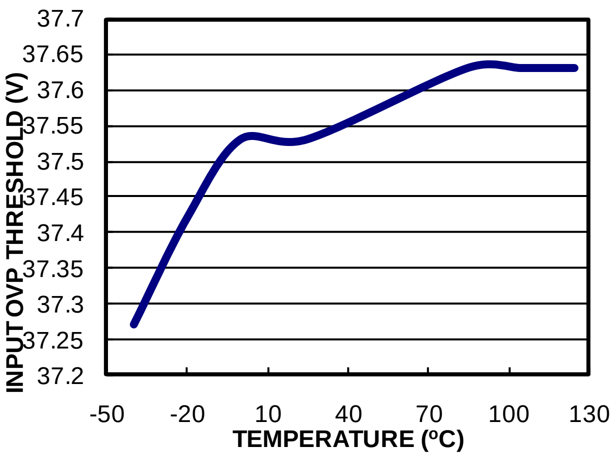
Bridge B LS On Resistance vs. Temperature

VIN = 24V, I_{OUT} = 1A



TYPICAL CHARACTERISTICS *(continued)*

Input OVP Threshold vs. Temperature

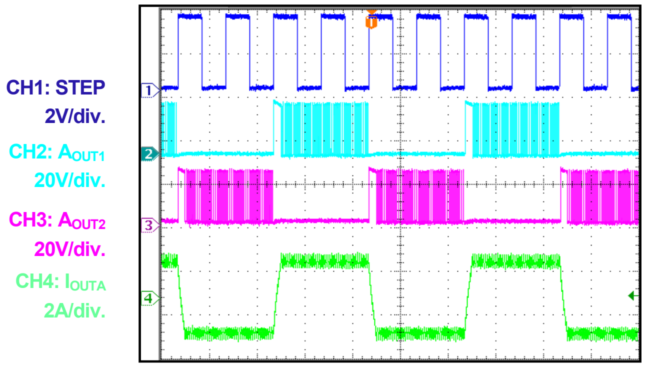


TYPICAL PERFORMANCE CHARACTERISTICS

VIN = 24V, I_{OUT} = 2.5A, F_{STEP} = 1kHz, T_A = 25°C, resistor + inductor load: R = 3.3Ω, L = 1.5mH/channel, unless otherwise noted.

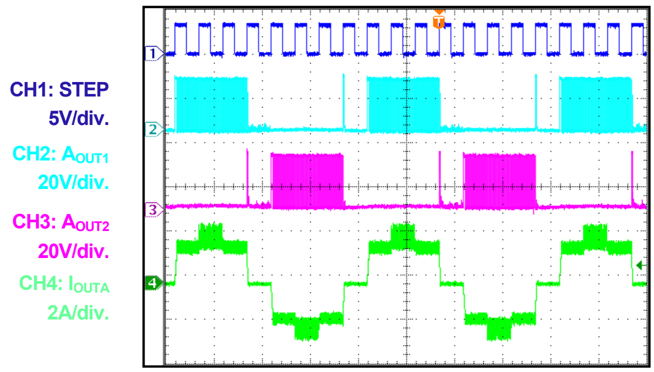
Steady State, Full Step

I_{OUT} = 2A



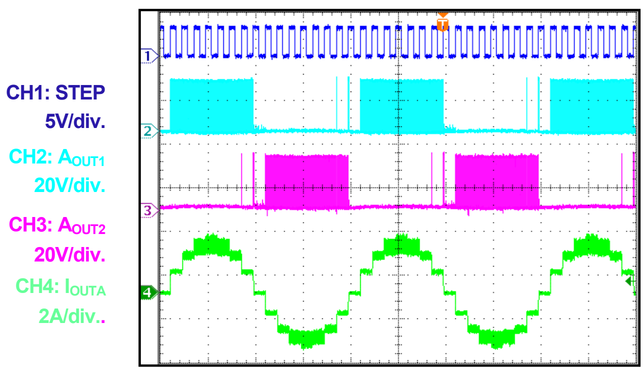
1ms/div.

Steady State, Half Step



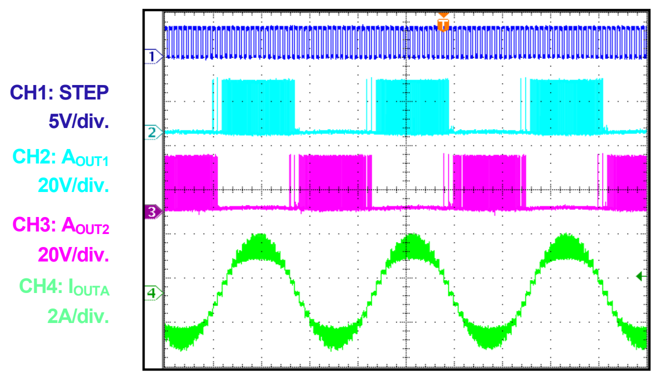
2ms/div.

Steady State, Quarter Step



4ms/div.

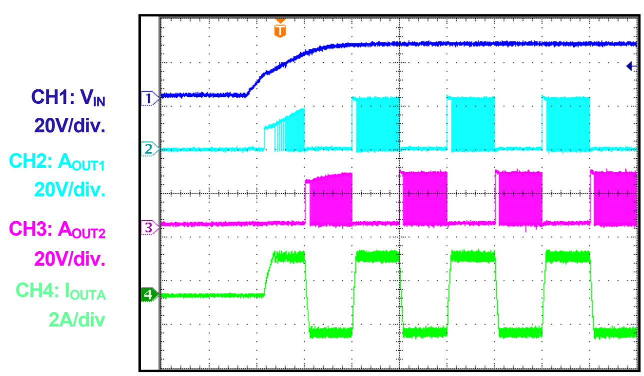
Steady State, Eighth Step



10ms/div.

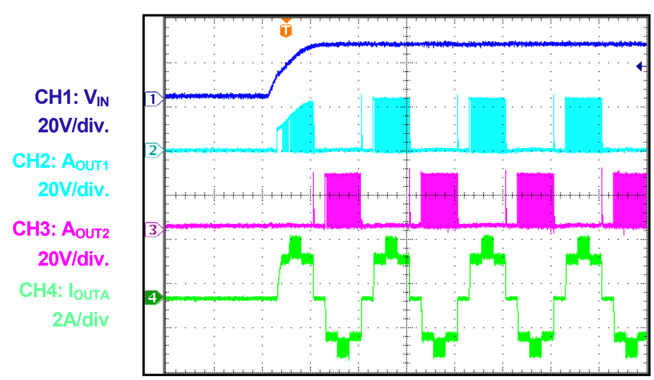
Power Ramp-Up, Full Step

I_{OUT} = 2A



2ms/div.

Power Ramp-Up, Half Step

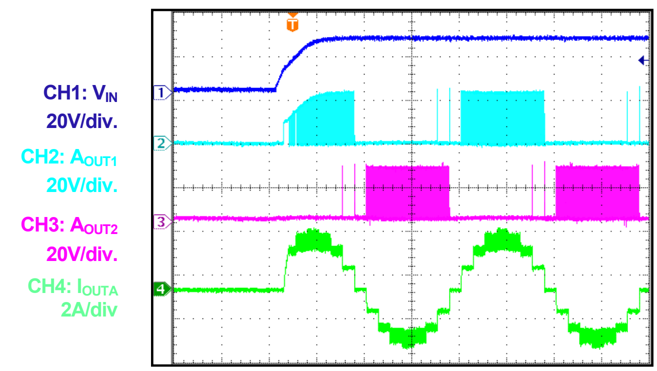


4ms/div.

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

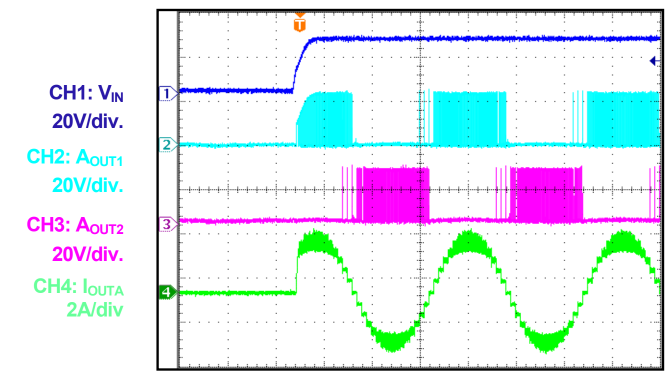
VIN = 24V, I_{OUT} = 2.5A, F_{STEP} = 1kHz, T_A = 25°C, resistor + inductor load: R = 3.3Ω, L = 1.5mH/channel, unless otherwise noted.

Power Ramp-Up, Quarter Step



4ms/div.

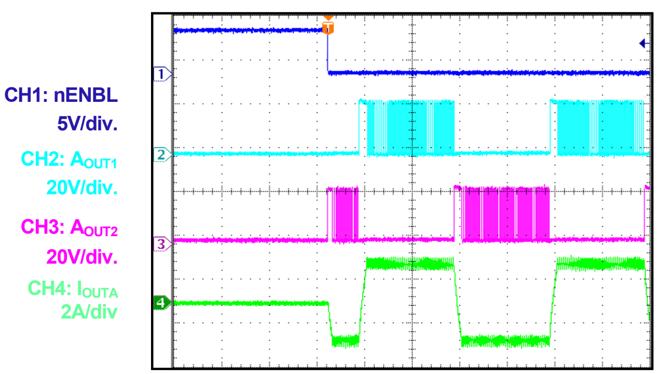
Power Ramp-Up, Eighth Step



10ms/div.

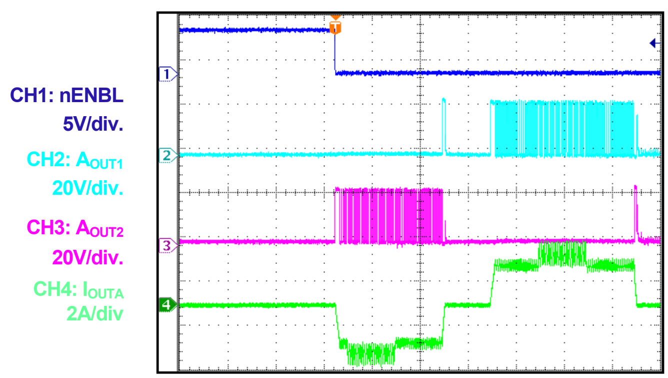
Enable, Full Step

I_{OUT} = 2A



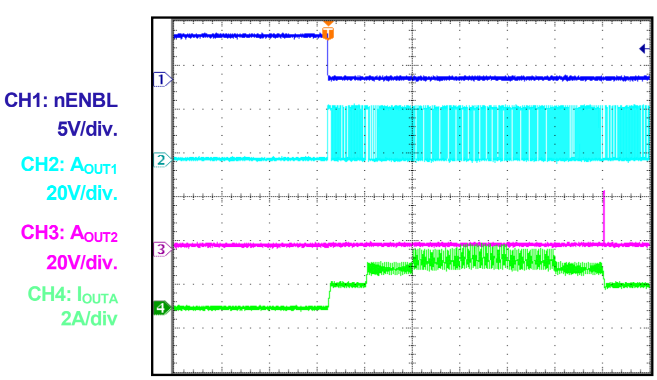
1ms/div.

Enable, Half Step



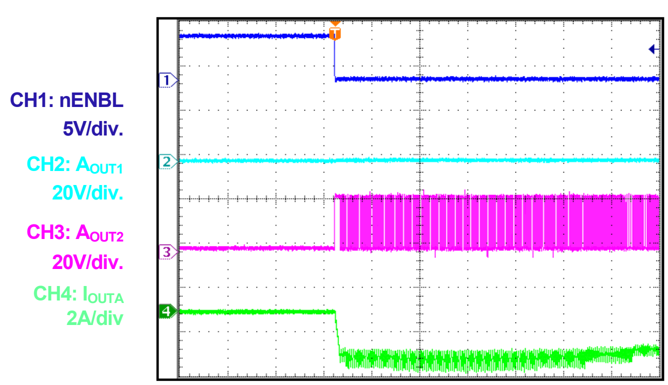
1ms/div.

Enable, Quarter Step



1ms/div.

Enable, Eighth Step



1ms/div.

PIN FUNCTIONS

Pin # QFN	Pin # TSSOP	Name	Description
1	11	DIR	**Direction input.** DIR has an internal pull-down resistor.
2	12	nFAULT	**Fault indication.** nFAULT is an open-drain output. Drive nFAULT to logic low when in a fault condition (OCP, OTP, OVP).
3	13	ISET	**Current set programming.** A resistor from ISET to ground sets the current through the motor.
4	14	AGND	**Analog ground.**
5	15	ROSC	**Constant off-time programming.** A resistor from ROSC to ground sets the PWM off time.
6	16	MS2	**Mode selection.** MS1 and MS2 set the step mode (full, 1/2, 1/4, or 1/8 step). MS1 and MS2 have an internal pull-down resistor.
7	18	MS1	
8, 12, 20, 24, EP	6, 10, 19, 23, EP	GND	**Power ground.**
9	20	BOUT1	**Bridge B output terminal 1.**
10, 22	8, 21	VIN	**Input supply voltage.** Both VIN pins must be connected to the same supply. Decouple VIN to ground with a minimum 100nF ceramic capacitor.
11	22	BOUT2	**Bridge B output terminal 2.**
13	24	STEP	**Step input.** The rising edge sequences the translator and advances the motor by one increment. STEP has an internal pull-down resistor.
14	25	VCP	**Charge pump output.** VCP requires a 1µF, 16V, ceramic capacitor to VIN.
15	28	CP2	**Charge pump capacitor.** Connect a 100nF ceramic capacitor rated for the VIN voltage between these terminals.
16	1	CP1	
17	2	VG	**Low-side MOSFETs gate drive voltage.** VG requires a 220nF, 16V, ceramic capacitor to ground.
-	3, 17, 26, 27	NC	**No connection.**
18	4	nENBL	**Enable input.** Drive nENBL to logic high to disable the bridge outputs and translator operation. Drive nENBL to logic low to enable the bridge outputs and translator operation. nENBL has an internal pull-down resistor.
19	5	nSLEEP	**Sleep mode input.** Drive nSLEEP to logic high to enable normal operation. nSLEEP has an internal pull-down resistor .
21	7	AOUT2	**Bridge A output terminal 2.**
23	9	AOUT1	**Bridge A output terminal 1.**

BLOCK DIAGRAM

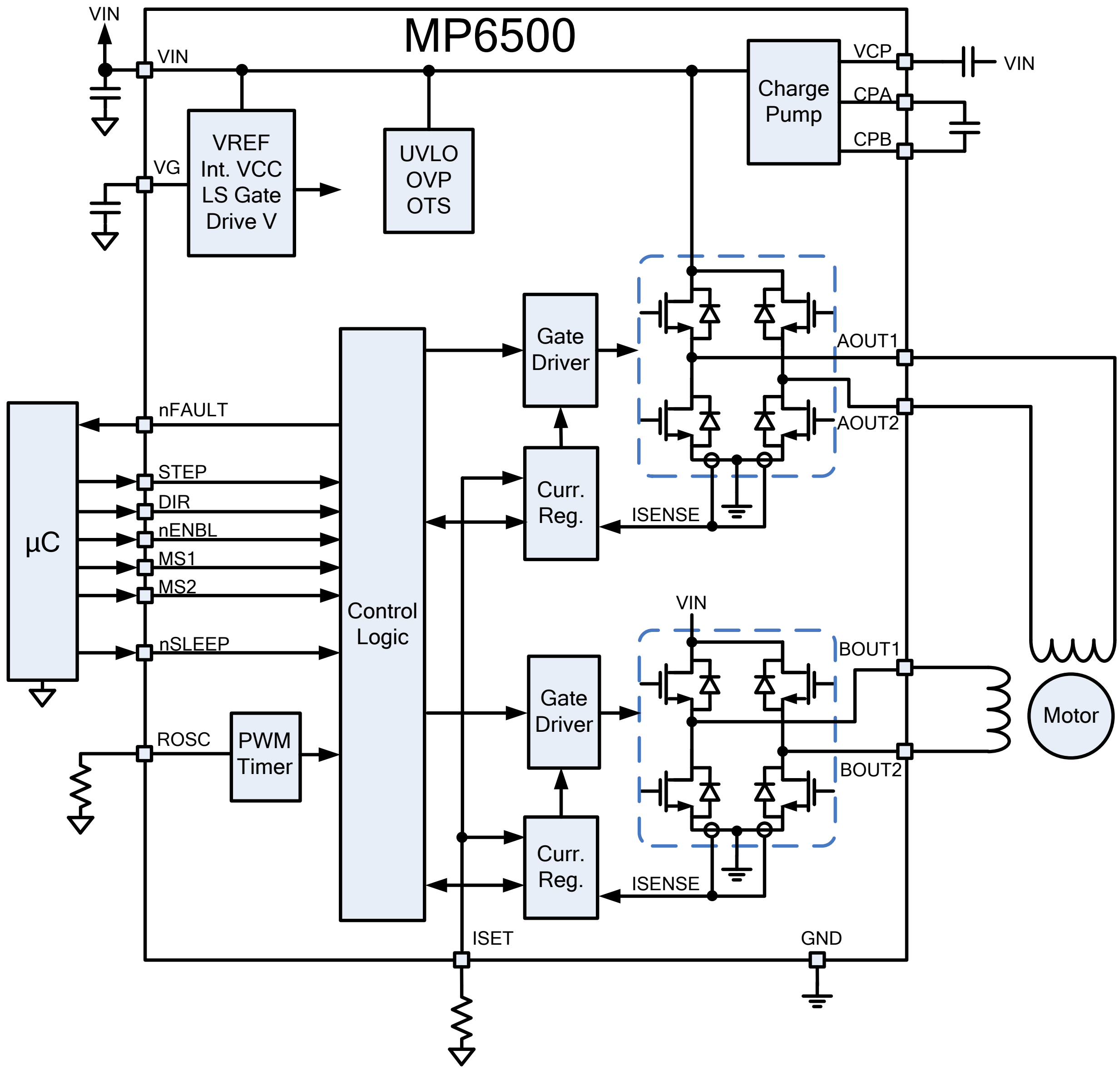


Figure 1: Functional Block Diagram

OPERATION

The MP6500 is a bipolar, stepper motor driver that integrates eight N-channel power MOSFETs arranged as two full-bridges with 2.5A of current capability each. The MP6500 operates over a wide 4.5V to 35V supply voltage range.

The MP6500 is designed to operate bipolar stepper motors in full-, half-, quarter-, and eighth-step modes. At each step, the current of each full-bridge is set by the output voltage of a DAC, which is controlled by the output of the translator.

The currents in each of the two outputs are regulated with programmable, constant off-time, pulse-width modulation (PWM) control circuitry. The MP6500 integrates internal current sensing with no external sense resistors required.

Stepping

The motor moves step-by-step by applying a series of pulses to STEP. A rising edge on the STEP input sequences the translator and advances the motor by one increment. The translator controls the input to the DACs and the direction of current flow in each winding. The amplitude of the increment (step size) is determined by the state of the inputs (MS1 and MS2) (see Table 1).

The state of DIR determines the direction of the rotation of the stepper motor.

The minimum STEP pulse width is 1µs. The logic control inputs MSx and DIR require at least 200ns of set-up time and hold time to the rising edge of the STEP input (see Figure 2).

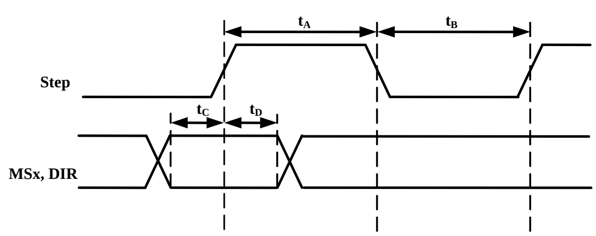


Figure 2: STEP Timing Diagram

Programmable Constant Off-Time Current Control

The motor current is regulated by a programmable constant off-time PWM current control circuit.

Initially, a diagonal pair of MOSFETs turns on and drives current through the motor winding. The current increases in the motor winding, which is sensed by an internal current sense circuit. During the initial blanking time (t_{BLANK}), the high-side MOSFET (HS-FET) always turns on in spite of current limit detection.

When the current reaches the current trip threshold, the internal current comparator either shuts off the HS-FET so the winding inductance current freewheels through the two low-side MOSFETs (LS-FET) (slow decay) or turns on another diagonal pair of MOSFETs so the current flows back to the input (fast decay). The current continues decreasing for the constant off-time duration unless a zero current level is detected. Afterward, the HS-FET is enabled to increase the winding current again. The cycle then repeats.

The constant off-time (t_{off}) is determined by the selection of an external resistor (R_{OSC}), which can be approximated with Equation (1):

$$t_{OFF}(ns) = 115 \times R_{OSC}(k\Omega) \quad (1)$$

The full-scale (100%) regulation current can be calculated with Equation (2):

$$I_{Max} = 78k\Omega / R_{ISET} \quad (2)$$

The DAC output reduces the trip current in precise steps. Calculate the trip current with Equation (3):

$$I_{Trip} = \%I_{Trip} \times I_{Max} \quad (3)$$

See Table 2 for $\%I_{Trip}$ at each step.

Blanking Time

There is usually a current spike during the switching transition due to the body diode's reverse-recovery current and the distributed winding capacitance of the motor. This current spike requires filtering to prevent it from erroneously shutting down the HS-FET.

After the PWM cycle begins, the output of the current sense comparator is ignored for the fixed blanking time. This blanking time results in a minimum on time for the PWM cycle.

Automatic Decay Mode

The MP6500 uses a fully automatic decay mode to provide accurate current regulation.

Initially, slow decay is used. At the end of the fixed off time, if the current is above the I_{TRIP} threshold, then fast decay mode is initiated by reversing the state of the H-bridge outputs.

Once the current level during this fast decay period drops below the I_{TRIP} threshold, slow decay is again engaged for another fixed off time. After the completion of this second fixed off time, a new PWM cycle begins.

Figure 3 below shows the automatic decay mode operation during a current reduction as a result of a step input.

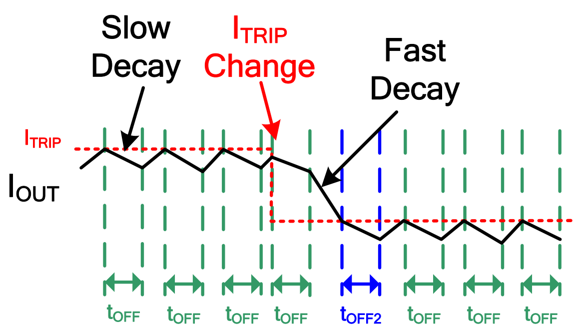


Figure 3: Slow Decay During t_{OFF} unless I_{OUT} > I_{TRIP} at end of t_{OFF}

In some cases, specifically high voltage and low inductance or the regulation of very small currents, the minimum on time of the PWM cycle (set by the blanking time described above) can cause the current to rise very quickly. In this case, both slow and fast decay are used (see Figure 4).

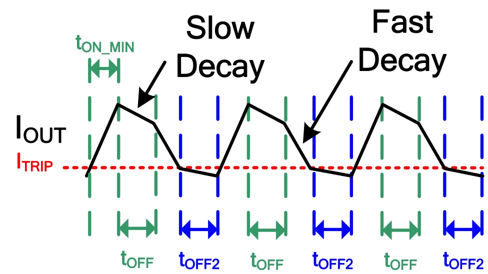


Figure 4: Current Regulation of Low Current/Low Inductance

Microstep Selection (MS1, MS2)

The step mode is selected by applying logic high and low voltages to the MS1 and MS2 (see Table 1). The MP6500 supports full-, half-, quarter-, and eighth-step modes for progressively finer step resolution and control.

Table 1: Stepping Format

MS2	MS1	STEP Mode
L	L	Full step
L	H	Half step
H	L	Quarter step
H	H	Eighth step

Full-step mode has four states with each motor winding driven with either 70.7% of the maximum positive current or 70.7% of the maximum negative current. This provides four steps per electrical rotation. Half-step mode creates eight steps per electrical rotation. Quarter- and eighth-step modes provide 16 and 32 steps per rotation respectively.

Table 2 and Figure 5 show the relative current level sequence for different settings of MSx.

The MSx pins have internal pull-down resistors.

SLEEP, nENBL Operation

Driving nSLEEP low puts the device into a low-power sleep state. In this state, the gate drive charge pump is stopped, and all the internal circuits and H-bridge outputs are disabled. All inputs are ignored when nSLEEP is active low.

When waking up from sleep mode, approximately 1ms of time must pass before a STEP command can be issued to allow the internal circuitry to stabilize. nSLEEP has an internal pull-down resistor.

The nENBL pin is used to control the output drivers. When nENBL is low, the output H-bridge outputs are enabled, and the rising edges on STEP are recognized. When nENBL is high, the H-bridge outputs are disabled, and the STEP input is ignored. nENBL has an internal pull-down resistor.

Fault Reporting

The MP6500 provides an nFAULT pin, which reports if a fault condition (such as OCP, OTP, or OVP) occurs. nFAULT is an open-drain output and is driven low when a fault condition occurs. If the fault condition is removed, nFAULT is pulled high by an external pull-up resistor.

Over-Current Protection (OCP)

Over-current protection (OCP) circuitry limits the current through the MOSFETs by disabling the gate driver. If the over-current limit threshold is exceeded for longer than the over-current deglitch time, all MOSFETs in the H-bridge are disabled, and nFAULT is driven low. The driver remains disabled for 2.4ms typically, at which time it is re-enabled automatically.

Over-current conditions on both high- and low-side devices (i.e.: a short to ground, supply, or across the motor winding) result in an over-current shutdown. Note that OCP does not use the current sense circuitry used for PWM current control.

Over-Voltage Protection (OVP)

If the input voltage on VIN is higher than the over-voltage protection (OVP) threshold, the H-bridge output is disabled, and nFAULT is driven low. This protection is released when VIN drops below 36V.

Input Under-Voltage Lockout (UVLO) Protection

If at any time the voltage on VIN falls below the under-voltage lockout (UVLO) threshold voltage, all circuitry in the device is disabled, and the internal logic is reset. Operation resumes when VIN rises above the UVLO threshold.

Thermal Shutdown

If the die temperature exceeds safe limits, all MOSFETs in the H-bridge are disabled, and nFAULT is driven low. Once the die temperature has fallen to a safe level, operation resumes automatically.

MICROSTEPPING

Table 2: Relative Current Level Sequence

Eighth Step #	Quarter Step #	Half Step #	Full Step #	Phase A Current $\%I_{Trip-LIMIT}$ (%)	Phase B Current $\%I_{TRIP-LIMIT}$ (%)	Step Angle (°)
1	1	1		100.00	0.00	0.0
2				98.08	19.51	11.3
3	2			92.39	38.27	22.5
4				83.15	55.56	33.8
5	3	2	1	70.71	70.71	45.0
6				55.56	83.15	56.3
7	4			38.27	92.39	67.5
8				19.51	98.08	78.8
9	5	3		0.00	100.00	90.0
10				-19.51	98.08	101.3
11	6			-38.27	92.39	112.5
12				-55.56	83.15	123.8
13	7	4	2	-70.71	70.71	135.0
14				-83.15	55.56	146.3
15	8			-92.39	38.27	157.5
16				-98.08	19.51	168.8
17	9	5		-100.00	0.00	180.0
18				-98.08	-19.51	191.3
19	10			-92.39	-38.27	202.5
20				-83.15	-55.56	213.8
21	11	6	3	-70.71	-70.71	225.0
22				-55.56	-83.15	236.3
23	12			-38.27	-92.39	247.5
24				-19.51	-98.08	258.8
25	13	7		0.00	-100.00	270.0
26				19.51	-98.08	281.3
27	14			38.27	-92.39	292.5
28				55.56	-83.15	303.8
29	15	8	4	70.71	-70.71	315.0
30				83.15	-55.56	326.3
31	16			92.39	-38.27	337.5
32				98.08	-19.51	348.8

MICROSTEPPING *(continued)*

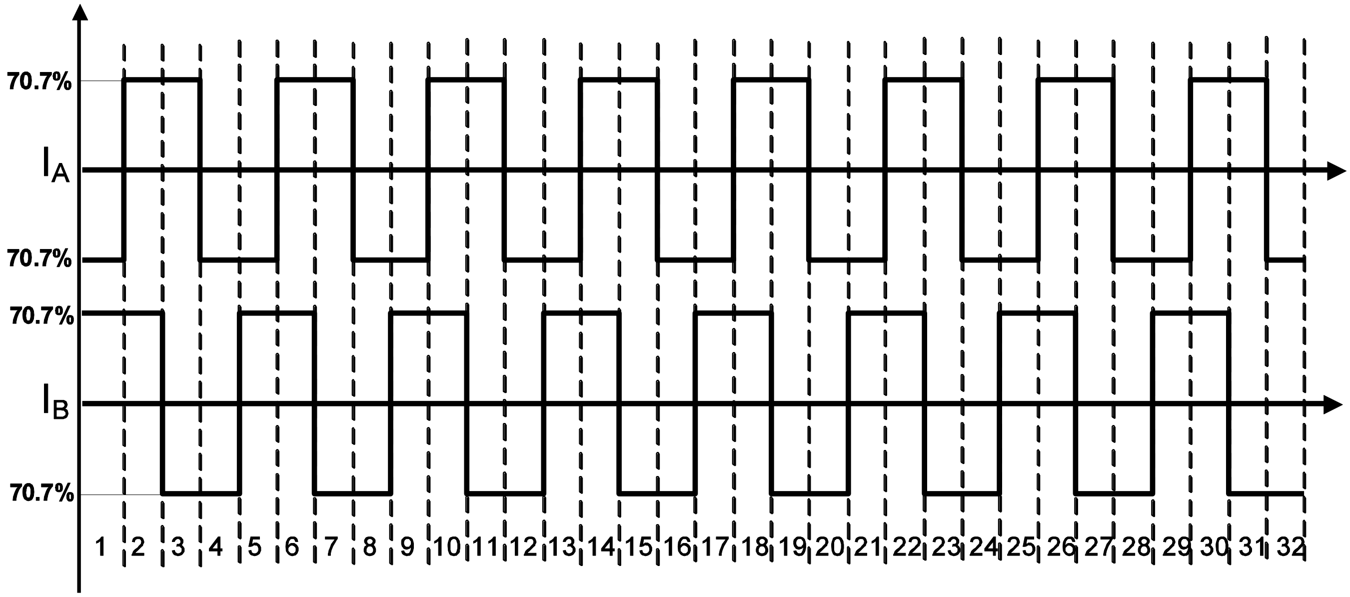


Figure 5a: Full Step (4 Step Sequences)

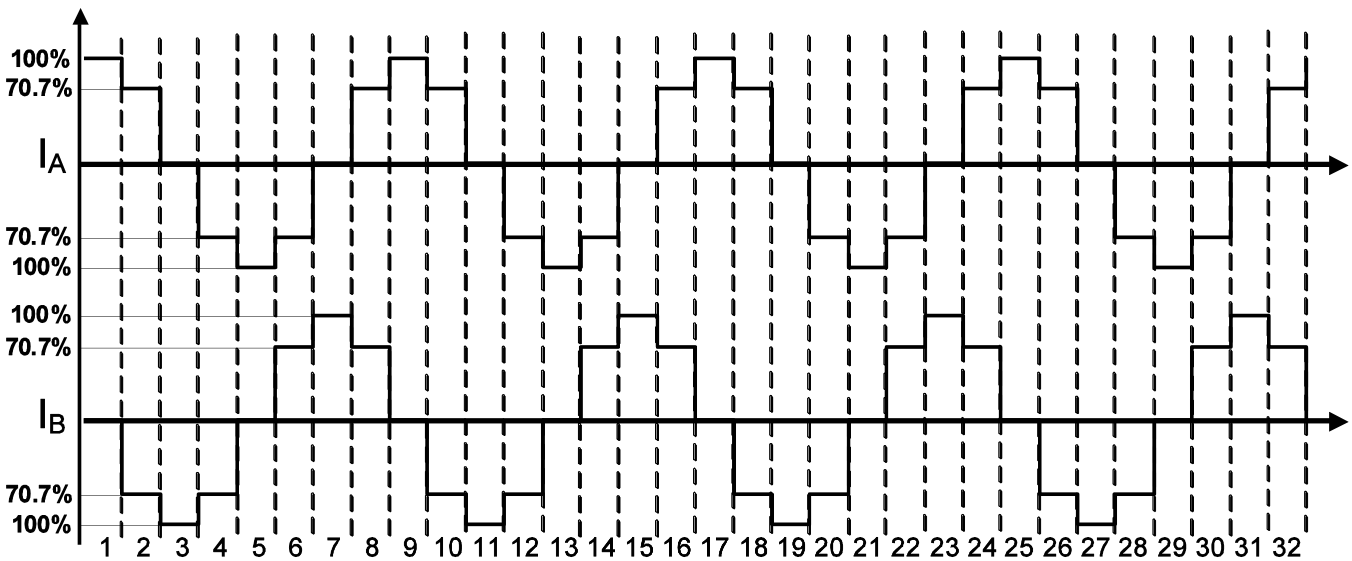


Figure 5b: Half Step (8 Step Sequences)

MICROSTEPPING *(continued)*

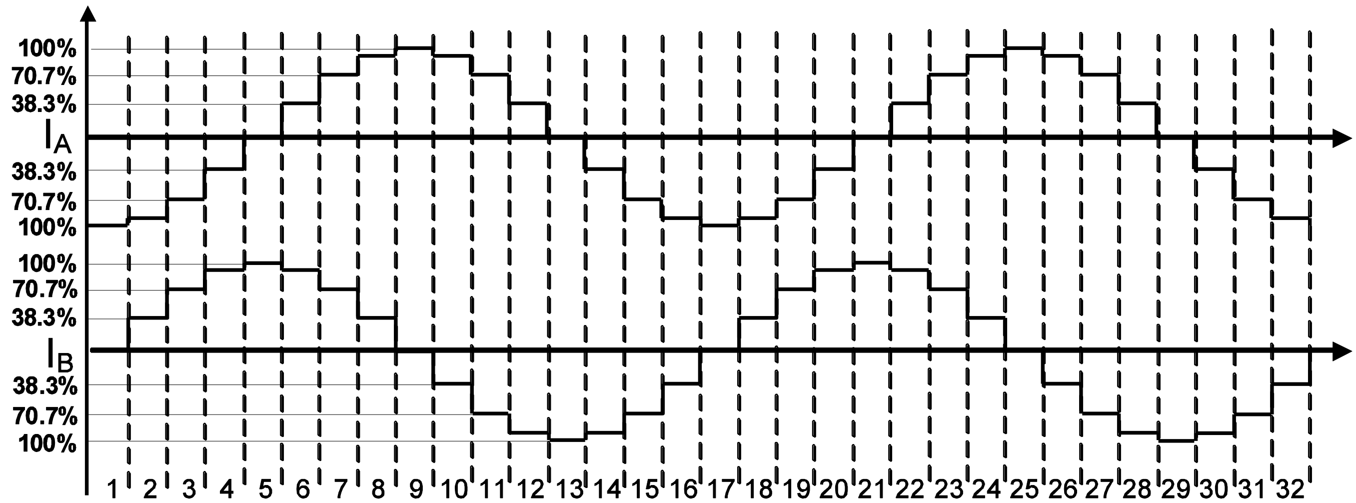


Figure 5c: Quarter Step (16 Step)

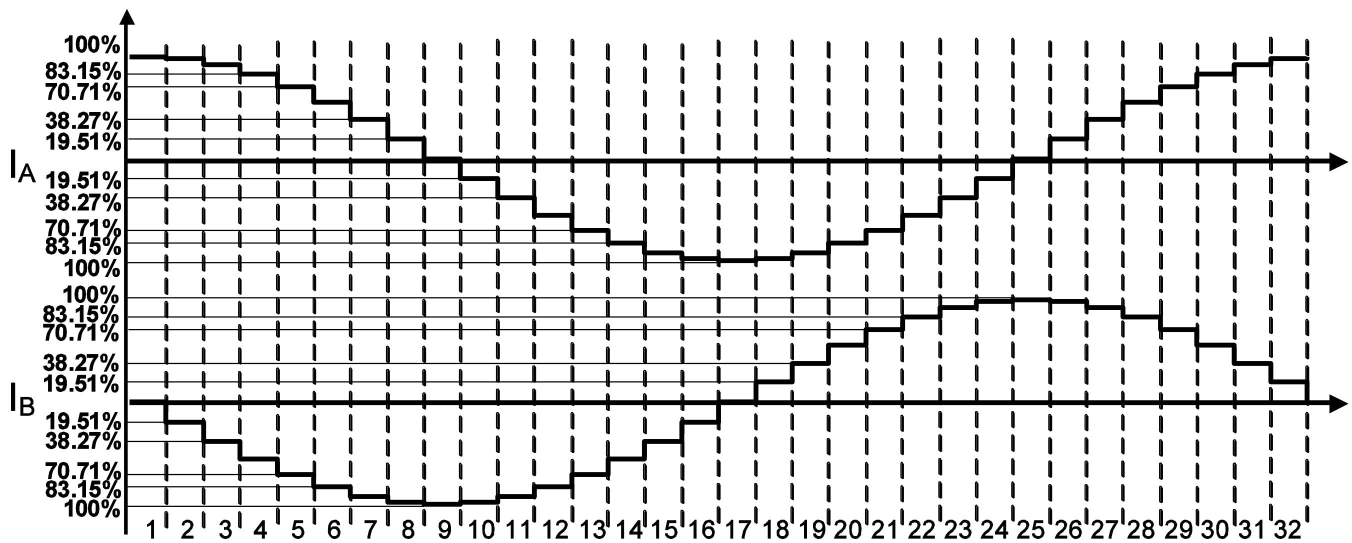
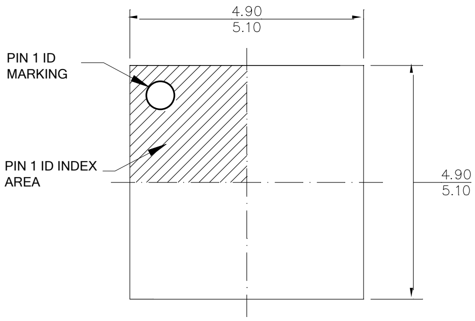


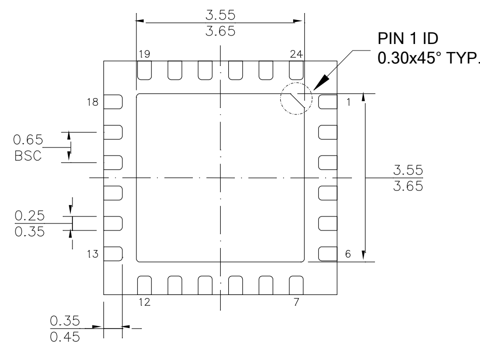
Figure 5d: Eighth Step (32 Step)

PACKAGE INFORMATION

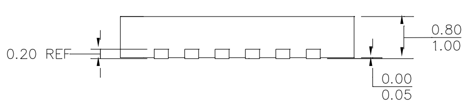
QFN-24 (5mmx5mm)



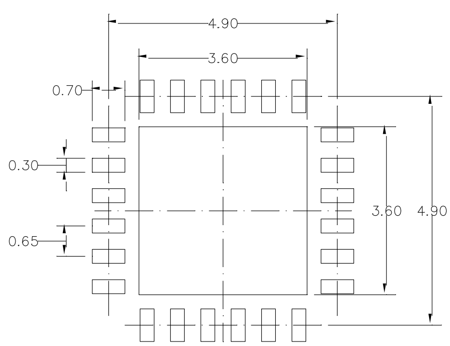
TOP VIEW



BOTTOM VIEW



SIDE VIEW



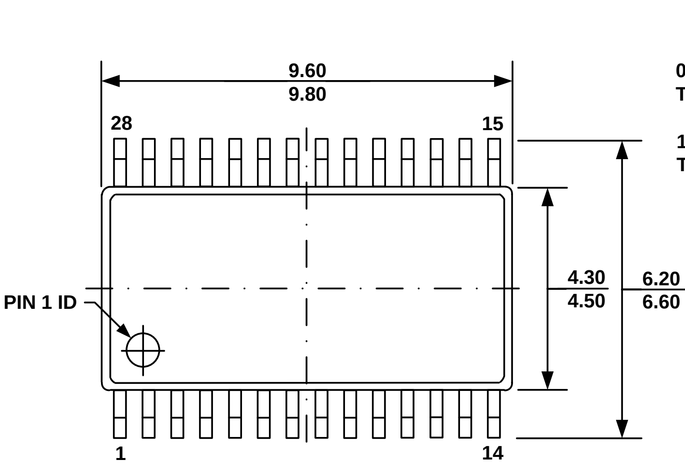
RECOMMENDED LAND PATTERN

NOTE:

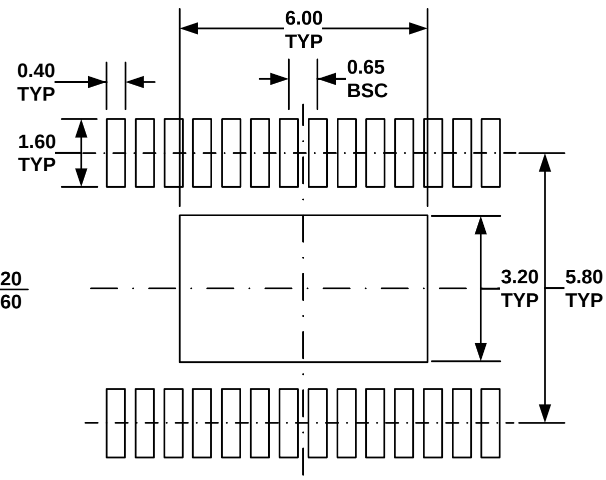
1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
4) DRAWING CONFIRMS TO JEDEC MO-220.
5) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION *(continued)*

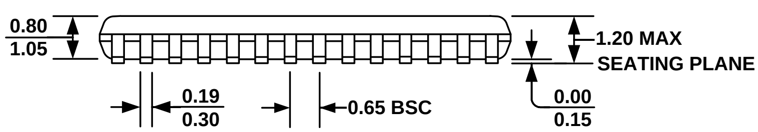
TSSOP-28 EP



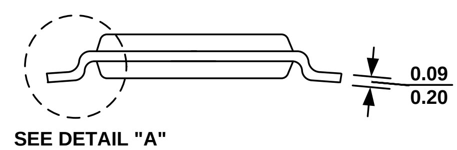
TOP VIEW



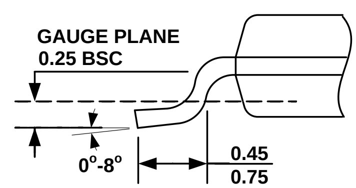
RECOMMENDED LAND PATTERN



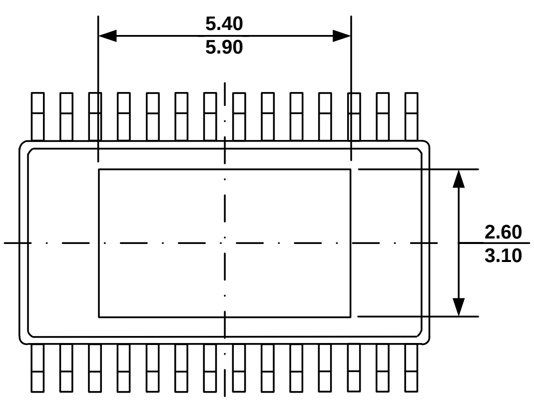
FRONT VIEW



SIDE VIEW



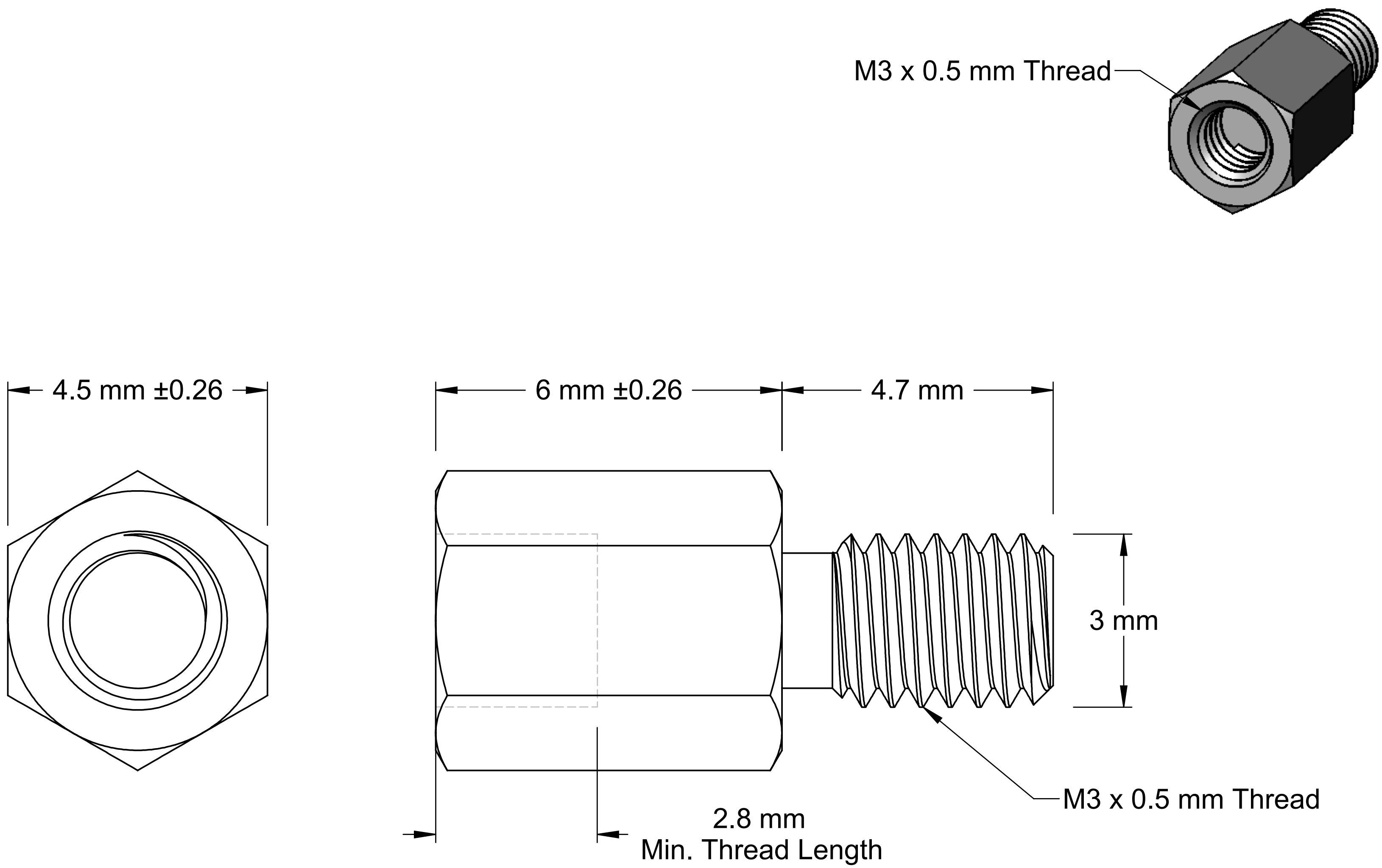
DETAIL "A"



BOTTOM VIEW

NOTE:

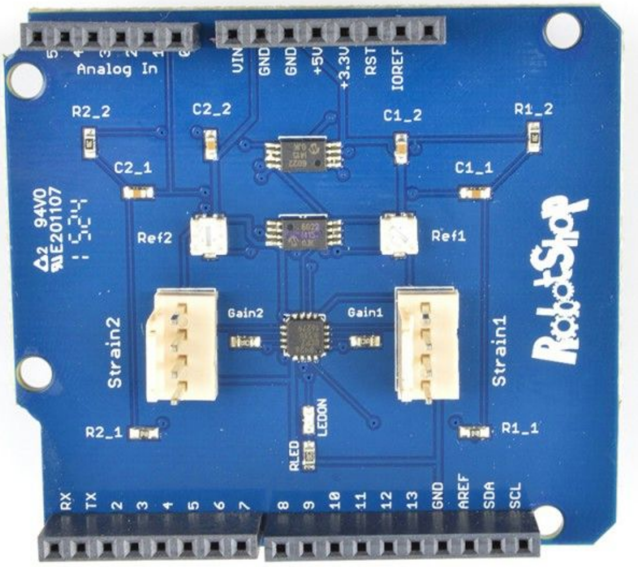
1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
5) DRAWING CONFORMS TO JEDEC MO-153, VARIATION AET.
6) DRAWING IS NOT TO SCALE.



WINE OPENER P/N: B612

McMASTER-CARR® CAD	PART NUMBER	95783A053
http://www.mcmaster.com © 2016 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Male-Female Threaded Hex Standoff	

Strain Gauge / Instrument Amplifier Shield



Revision 1.2 January 2016

Table of Contents

1. Overview

The Strain Gauge / Instrument Amplifier shield (SGS from here on further) is intended for precise amplification of measurements specifically for bridge amplifiers, medical instrumentation and industrial process control. The shield is intended to be used with normal shield-compatible Arduino-based microcontroller boards such as the Arduino Uno.

Instrumentation signals of small values, in the order of mV (millivolts) or less, need to be amplified for processing. Prototyping boards like the Arduino Uno normally have a 10 bit ADC which means that the resolution of input/outputs are 4.9mV for a 5V (will be different for 3.3V or other referencing voltages) supply. Therefore changes less than 4.9mV cannot be easily recognized by the process board without the necessary amplification and possible noise filtering.

The AD8426 was selected to be used as the amplifier for the shield. The gain produced by the AD8426 amplifier ranges from 1 to 1000 depending on the RGAIN resistor value. Another valuable feature is the voltage reference adjustment on board to adjust the output voltage reference in order to be used with a single power supply ADC, which the Arduino makes use of.

For filtering, a second order Bessel low pass filter for 1k Hz was designed to help smooth out unwanted interference.

This shield is known to work with the Arduino UNO/Duemilanove boards. For all other shield-compatible boards, please consult the pinout / schematic.

1.1 Pinout

The SGS uses the following pins:

- A0: Strain 1 input
- A1: Strain 2 input
- 5V, 3.3V and GND pins are used to power the shield

The white connectors on the board are 4 pin Molex connectors with 0.1” spacing. Note that a standard 0.1” spaced connector can be used to connect to this header.

2. Strain Gauges

Strain gauges are essentially sensors which produce a very small change in resistance when sensing strain. Strain gauges can be substituted with output characteristics of different sensors for specific applications.

Strain measurements relay the actual strain experienced by a material when a force is applied to it, whether it is a linear, axial, compressive or expansion force. A good educational reference is http://en.wikipedia.org/wiki/Stress%E2%80%93strain_curve which explains the science behind strain in materials.

2.1 Strain Gauge Characteristics

Good explanations on how strain gauges operate and the basic science behind them can be found on the following websites:

- http://www.ni.com/white-paper/3092/en/
- http://en.wikipedia.org/wiki/Strain_gauge
- http://en.wikipedia.org/wiki/Load_cell
- http://www.sensorland.com/HowPage002.html
- https://www.youtube.com/watch?v=D3J41HE_RMA
- https://www.youtube.com/watch?v=cP5rs3YIcbo

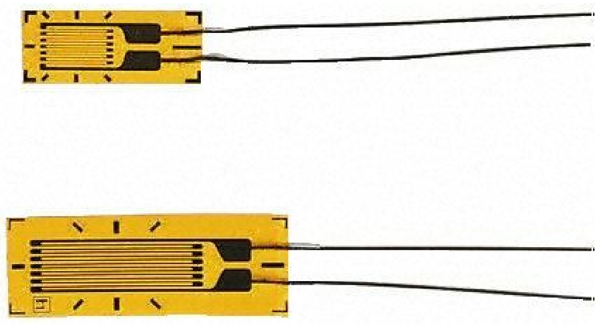


Figure 2: Strain Gauge.

2.2 Wheatstone bridges

A “Wheatstone bridge” is the principal layout for certain sensors which use the electrical properties of the circuit to extract useful information. The SGS without the Wheatstone bridge would only be a differential amplifier with a high sensitivity for weak signals.

There are different configurations of Wheatstone bridges depending on the sensitivity and magnitude of the signal produced by the sensing element(s), which in this case is a strain gauge. The Wheatstone bridge can also adjust for certain initial offset imbalances or for outside factors that influence the sensing element like temperature as shown in the reference links in section 3.1.

The following references explains the setup of the Wheatstone bridge:

- http://www.hbm.com.pl/pdf/w1569.pdf
- http://www.transducertechniques.com/wheatstone-bridge.aspx

Pin layout and cable colours for many Wheatstone sensors:

Identification	Molex pin number	Normal Cable Colour
VCC	1	Red
S+	2	Green
S-	3	Blue
GND	4	Black

Table 1: Pin connection with cable colours of pigtails

3. Circuit Building blocks

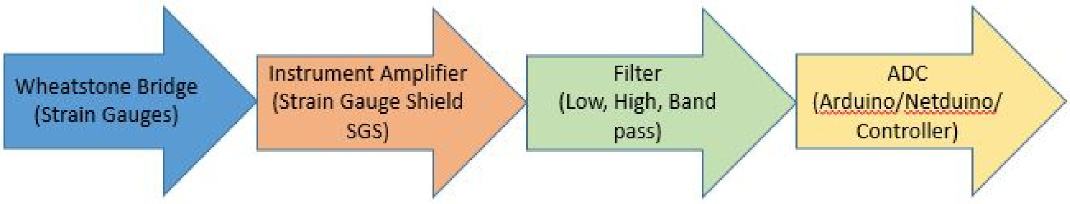


Figure 3: High-level block diagram

The following sub-paragraphs will explain more about the different building blocks.

3.1 Strain Gauge Inputs via Wheatstone bridges

See chapter 2 for more detail.

3.2 Instrumentation Amplifier

The instrumentation amplifier used, AD8426, is a differential amplifier. The datasheet will show all the electronic characteristics of this amplifier. There are two changes per channel that can be adjusted for the specific use of the SGS, which are:

Gain: The gain (amplification per channel) through the amplifier is dependent on the resistor value RGAIN1/2 marked as Gain1/Gain2 on the board layout. The gain factor needs to be picked based on the specific application and sensitivity of the total Wheatstone bridge with the strain gauges incorporated. Take note that the gain achieved on the input from the Wheatstone bridge does not exceed the maximum voltage of 3.3V or 5V.

Figure 4 shows the values that RGAIN1/2 should be made to get the required gain per application. The standard RGAIN1/2 value selected, 100 Ohms for the SGS, is in the general selection range for applications with Wheatstone bridge Strain gauges. Figure 5 shows the actual position of where the RGAIN1/2 resistors were placed. If a different gain might be required that is different than the setup gain of 495 with a 100 ohm resistor just replace it with the appropriate resistor.

1% Standard Table Value of R_G	Calculated Gain
49.9 kΩ	1.990
12.4 kΩ	4.984
5.49 kΩ	9.998
2.61 kΩ	19.93
1.00 kΩ	50.40
499 Ω	100.0
249 Ω	199.4
100 Ω	495.0
49.9 Ω	991.0

The AD8426 defaults to G = 1 when no gain resistor is used. The tolerance and gain drift of the R_G resistor should be added to the AD8426 specifications to determine the total gain accuracy of the system. When the gain resistor is not used, gain error and gain drift are minimal.

Figure 4. Extract from the AD8426 datasheet

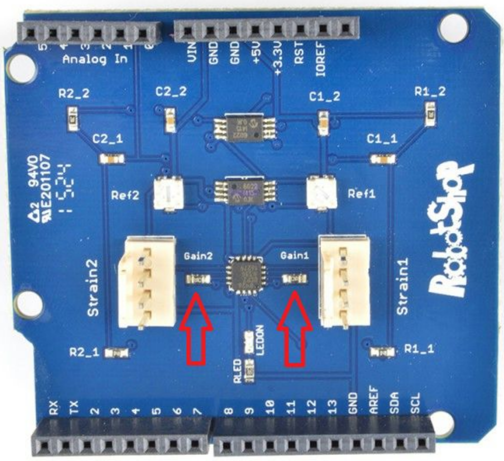


Figure 5: RGAIN positions on SGS

Reference voltage per channel: The reference voltage is used to offset the output signal to a mid-supply voltage in order to be used with a single power supply ADC which is part of the Duino boards in use. Each Strain channel has its own reference voltage to be set with the specific channel potentiometer as shown in Figure 6.

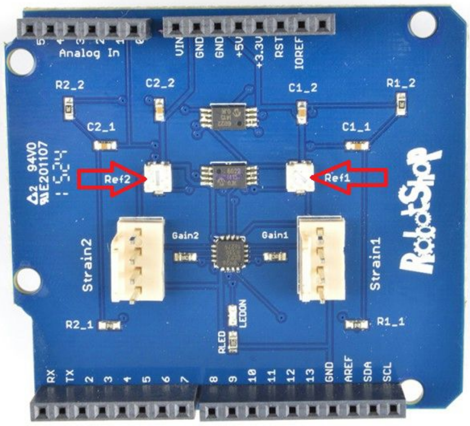


Figure 6: Reference potentiometers positions on SGS.

3.3 Filter

The SGS has been fitted with a low-pass 2nd order Bessel filter at 1000 Hz for both channels after the instrument amplifier before it is read by the Arduino Analog input pins A0 (Strain1) and A1 (Strain2). The filter can easily be adjusted by replacing the resistor values (R1_1, R1_2, R2_1 and R2_2) and capacitor values (C1_1, C1_2, C2_1 and C2_2) for the specific frequency that might be required. Component names R1_1, R1_2, C1_1 and C1_2 are related to channel one (First number of component indicates the channel number it is associated with). Component names R2_1, R2_2, C2_1 and C2_2 related to channel 2.

For ease of reference to adjust the filter one can use the Freeware program FilterLab (http://filterlab.software.informer.com/2.0/) to calculate the required values of the 2nd order Bessel filter to cater for the necessary frequencies if the setup 1000 Hz is not sufficient for the user.

It is also possible to change the low-pass filter to a high-pass filter if need be, because the resistors and capacitors can change places (resistors and capacitors are 0603 specified packaging) for easy placement on the PCB.

3.4 ADC

The Arduino board contains a 10 bit analog to digital converter (ADC). It will convert input voltages between 0 and 5 volts into integer values between 0 and 1023. The resolution of the ADC is

5V/1024 units = 4.9mV per unit. it takes 100 microseconds to read an analog input, so the sampling frequency of the ADC is 10kHz.

4. Arduino Sample Code / Calibration

The following Arduino code reads Analog pin 0 (Strain 1) and Analog pin 1 (Strain 2) so the load cells can be calibrated by linear interpolation. Note: These steps are the same for the two outputs.

1. Copy / paste the code below to the Arduino IDE.
2. Upload the code to your Arduino board.
3. Once done, open the Arduino serial monitor.
4. Apply the first known load and note reading.
5. Apply the second known load and note the reading.
6. Edit the values of ReadingA_Strain1 and ReadingB_Strain1 with the taken readings within the code.
7. Edit the values of LoadA_Strain1 and LoadB_Strain1 with the correct load measured in Kg, Lbs …
8. Upload the code to the Arduino board and retest the known loads.
9. Try an unknown load.

```
// SGS Calibration by linear interpolation for Strain 1 and Strain 2
// Apply two known loads to the Strain Gauge sensor and record the values obtained below
// You can use Strain 1 or Strain 2 or the two Strains at the same time.

float ReadingA_Strain1 = 301.0;
float LoadA_Strain1 = 0.0;              //  (Kg,lbs..)
float ReadingB_Strain1 = 302.0;
float LoadB_Strain1 = 80.0;             //  (Kg,lbs..)
float ReadingA_Strain2 = 1.0;
float LoadA_Strain2 = 0.0;              //  (Kg,lbs..)
float ReadingB_Strain2 = 60.0;
float LoadB_Strain2 = 80.0;             //  (Kg,lbs..)
int time_step = 2500 ;                  // reading every 2.5s
long time = 0;

void setup() {
 Serial.begin(9600);                    //  setup serial baudrate
}

void loop() {
 float newReading_Strain1 = analogRead(0);  // analog in 0 for Strain 1
 float newReading_Strain2 = analogRead(1);  // analog in 1 for Strain 2

// Calculate load by interpolation
 float load_Strain1 = ((LoadB_Strain1 - LoadA_Strain1)/(ReadingB_Strain1 - ReadingA_Strain1)) *
(newReading_Strain1 - ReadingA_Strain1) + LoadA_Strain1;
 float load_Strain2 = ((LoadB_Strain2 - LoadA_Strain2)/(ReadingB_Strain2 - ReadingA_Strain2)) *
(newReading_Strain2 - ReadingA_Strain2) + LoadA_Strain2;

 // millis returns the number of milliseconds since the board started the current program
if(millis() > time_step+time) {
   Serial.print("Reading_Strain1 : ");
   Serial.print(newReading_Strain1);    // display strain 1 reading
   Serial.print("  Load_Strain1 : ");
   Serial.println(load_Strain1);        // display strain 1 load
   Serial.println('\n');
   Serial.print("Reading_Strain2 : ");
   Serial.print(newReading_Strain2);    // display strain 2 reading
   Serial.print("  Load_Strain2 : ");
   Serial.println(load_Strain2);        // display strain 2 load
   Serial.println('\n');
   time = millis();
 }
}
```

5. Support / Warranty

A warranty of 30 days is provided for this product starting from the day the product is received by the customer. Any questions relating to the proper use of this product, or issues encountered should be addressed to supportcenter@robotshop.com

MP6500

35V, 2.5A, Stepper Motor Driver

DESCRIPTION

The MP6500 is a stepper motor driver with a built-in translator and current regulation. Current sensing is internal and requires no external sense resistors. High integration and a small package size make the MP6500 a space-saving and cost-effective solution for bipolar stepper motor drives.

The MP6500 operates from a supply voltage of up to 35V and can deliver motor currents up to 2.5A (depending on PCB design and thermal conditions). The MP6500 can operate a bipolar stepper motor in full-, half-, quarter-, or eighth-step modes. Internal safety features include over-current protection (OCP), input over-voltage protection (OVP), under-voltage lockout (UVLO), and thermal shutdown.

The MP6500 is available in QFN-24 (5mmx5mm) and TSSOP-28 EP packages.

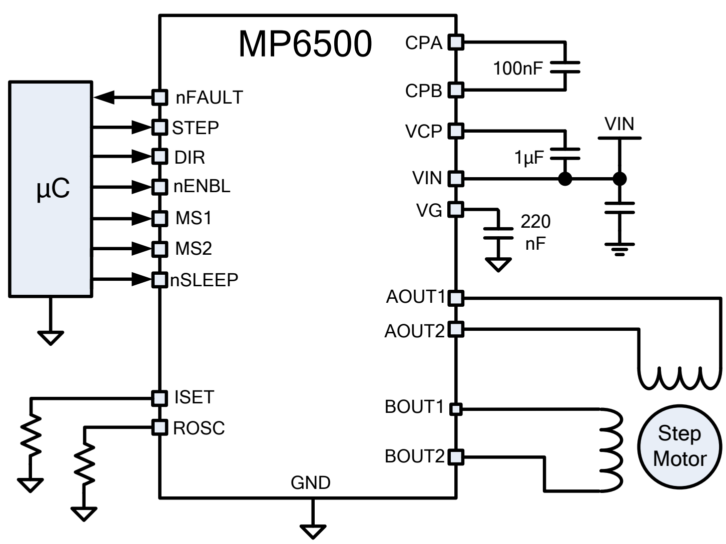
FEATURES

- Wide 4.5V to 35V Input Voltage Range
- Two Internal Full-Bridge Drivers
- Internal Current Sensing and Regulation
- Low On Resistance (HS: 195mΩ, LS: 170mΩ)
- No Control Power Supply Required
- Simple Logic Interface
- 3.3V and 5V Compatible Logic Supply
- Step Modes from Full-Step to Eighth-Step
- 2.5A Output Current
- Automatic Current Decay
- Over-Current Protection (OCP)
- Input Over-Voltage Protection (OVP)
- Thermal Shutdown and Under-Voltage Lockout (UVLO) Protection
- Fault Indication Output
- Available in QFN-24 (5mmx5mm) and Thermally Enhanced TSSOP-28 Packages

APPLICATIONS

- Bipolar Stepper Motors
- Printers

TYPICAL APPLICATION



ORDERING INFORMATION

Part Number*	Package	Top Marking
MP6500GF*****	TSSOP-28 EP	*See Below*
MP6500GU******	QFN-24 (5mmx5mm)	*See Below*

* For Tape & Reel, add suffix –Z (e.g. MP6500GF–Z)
** For Tape & Reel, add suffix –Z (e.g. MP6500GU–Z)

TOP MARKING

MPSYYWW
MP6500
LLLLLLLLL

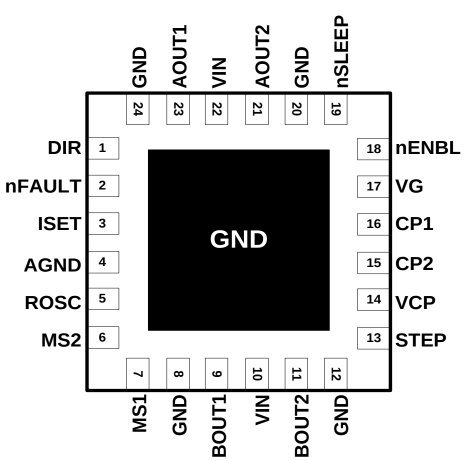
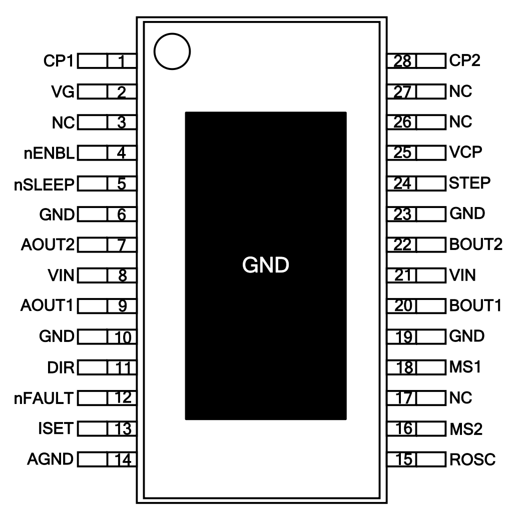
MPS: MPS prefix
YY: Year code
WW: Week code
MP6500: Part number
LLLLLLLLL: Lot number

TOP MARKING

MPSYYWW
MP6500
LLLLLLL

MPS: MPS prefix
YY: Year code
WW: Week code
MP6500: Part number
LLLLLLL: Lot number

PACKAGE REFERENCE

TOP VIEW	TOP VIEW
	
QFN-24 (5mmx5mm)	**TSSOP-28 EP**

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (VIN) .... -0.3V to 40V
xOUTx voltage ($V_{A/BOUT1/2}$) .... -0.7V to 40V
VCP, CPB .... VIN to VIN + 6.5V
All other pins to AGND .... -0.3V to 6.5V
ESD rating (HBD) 2kV
Continuous power dissipation (T_A = +25°C) (2)
QFN 3.5W
TSSOP 3.9W
Storage temperature .... -55°C to +150°C
Junction temperature .... +150°C
Lead temperature (solder) .... +260°C

Recommended Operating Conditions (3)

Supply voltage (VIN) .... 4.5V to 35V
Output current ($I_{A,BOUT}$) .... ±2.5A
Operating junction temp. (T_J) .. -40°C to +125°C

Thermal Resistance (4)	θ_{JA}	θ_{JC}	
QFN-25 (5mmx5mm)	36	8	°C/W
TSSOP-28 EP	32	6	°C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

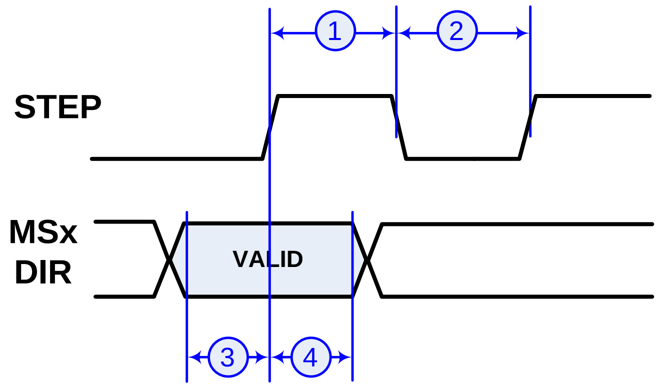
VIN = 24V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Power Supply						
Input supply voltage	V_{IN}		4.5	24	35	V
Quiescent current	I_Q	VIN = 24V, nENBL = 0, nSLEEP = 1, with no load		1.5	5	mA
	I_{SLEEP}	VIN = 24V, nSLEEP = 0			1	µA
Internal MOSFETs						
Output on resistance	R_{HS}	VIN = 24V, I_{OUT} = 1A, T_J = 25°C		0.195	0.22	Ω
		VIN = 24V, I_{OUT} = 1A, T_J = 85°C		0.25		Ω
	R_{LS}	VIN = 24V, I_{OUT} = 1A, T_J = 25°C		0.17	0.21	Ω
		VIN = 24V, I_{OUT} = 1A, T_J = 85°C		0.25		Ω
Body diode forward voltage	V_F	I_{OUT} = 1.5A			1.1	V
Control Logic						
Input logic low threshold	V_{IL}				0.8	V
Input logic high threshold	V_{IH}		2.1			V
Logic input current	$I_{IN(H)}$	V_{IH} = 5V			20	µA
	$I_{IN(L)}$	V_{IL} = 0.8V			5	µA
Internal pull-down resistance	R_{PD}			500		kΩ
Home nFAULT Outputs (Open-Drain Outputs)						
Output low voltage	V_{OL}	I_O = 5mA			0.5	V
Output high leakage current	I_{OH}	V_O = 3.3V			1	µA
Protection Circuit						
UVLO rising threshold	V_{IN_RISE}			3.4	4.5	V
Input OVP threshold	V_{OVP}		36	37.5	38.5	V
Input OVP hysteresis	ΔV_{OVP}			1900		mV
Over-current trip level	I_{OCP1}	Sinking	3.5	6	8.5	A
	I_{OCP2}	Sourcing	3.5	6	8.5	A
Over-current deglitch time	t_{OCP}			1		µs
Thermal shutdown	T_{TSD}			165		°C
Thermal shutdown hysteresis	ΔT_{TSD}			15		°C
Current Regulation						
Constant off time	t_{OFF}	R_{osc} = 200kΩ	20	23	26	µs
Peak current regulation level	I_{PEAK}	R_{ISET} = 78kΩ	0.95	1.0	1.05	A
ISET voltage	V_{ISET}		0.8	0.9	1	V
ISET current ratio	A_{ISET}	I_{ISET}/I_{OUT}	10	11.539	13	µA/A
Blanking time	t_{BLANK}			2		µs
Current trip accuracy	ΔI_{TRIP}	R_{ISET} = 78kΩ, 71% - 100%	-5		5	%
		R_{ISET} = 78kΩ, 38% - 67%	-9		9	%
		R_{ISET} = 78kΩ, <34%	-12		12	%

TIMING CHARACTERISTICS

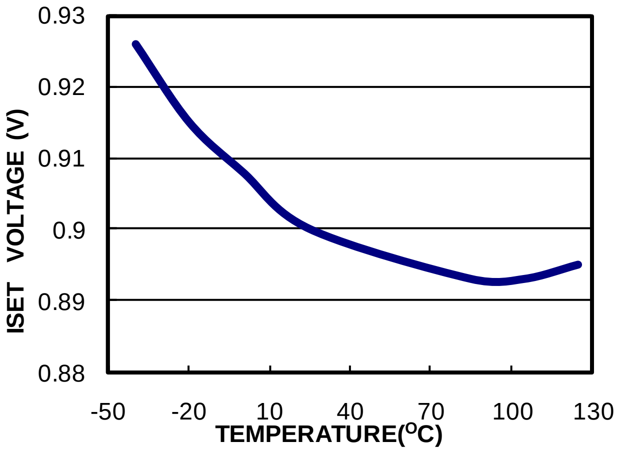
VIN = 24V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
STEP high time	t1		1			µs
STEP low time	t2		1			µs
Setup time MSx, DIR to STEP rising	t3		200			ns
Hold time STEP rising to MSx, DIR change	t4		200			ns

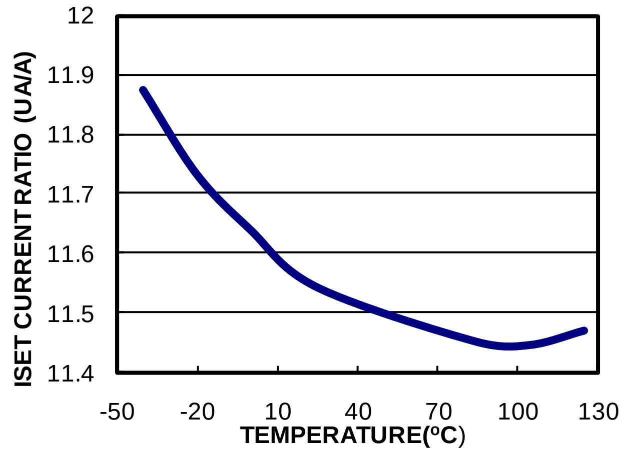


TYPICAL CHARACTERISTICS

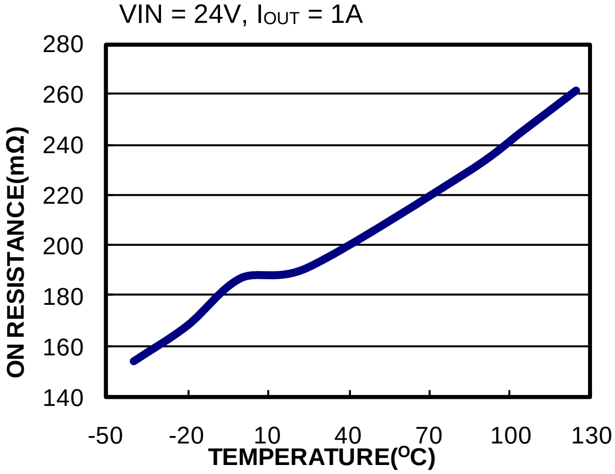
ISET Voltage vs. Temperature



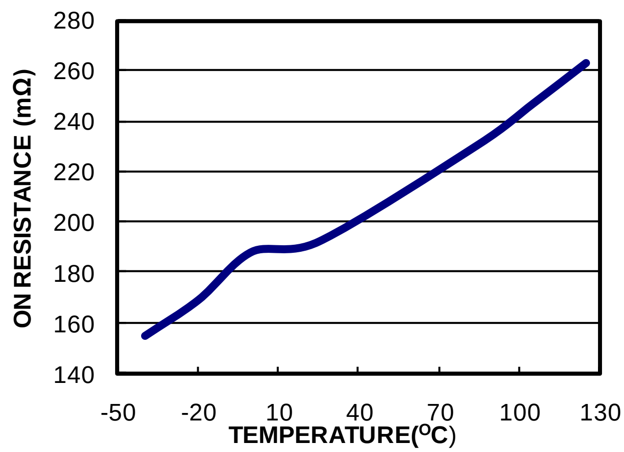
ISET Current Ratio vs. Temperature



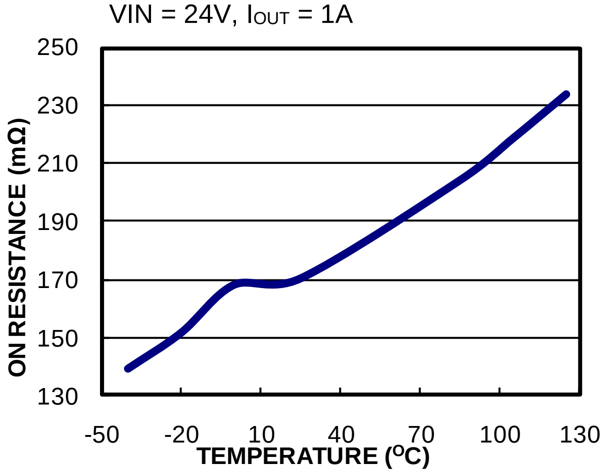
Bridge A HS On Resistance vs. Temperature
VIN = 24V, I_{OUT} = 1A



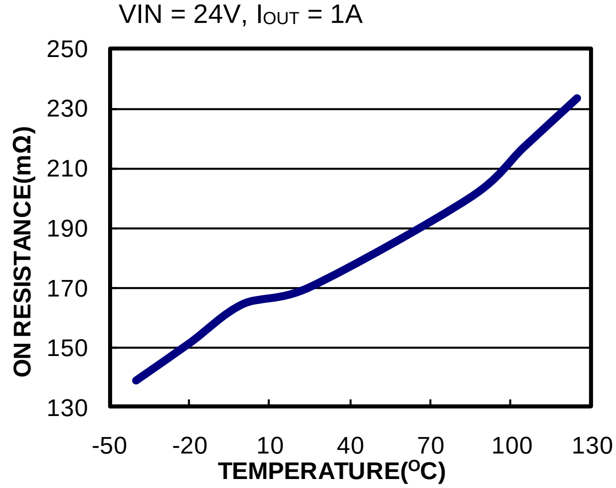
Bridge B HS On Resistance vs. Temperature
VIN = 24V, I_{OUT} = 1A



Bridge A LS On Resistance vs. Temperature
VIN = 24V, I_{OUT} = 1A

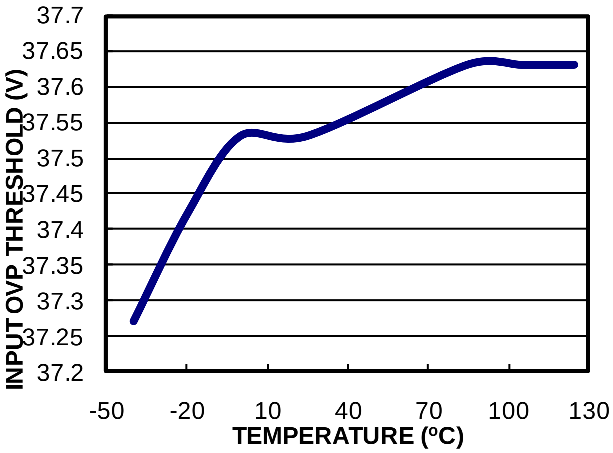


Bridge B LS On Resistance vs. Temperature
VIN = 24V, I_{OUT} = 1A



TYPICAL CHARACTERISTICS *(continued)*

Input OVP Threshold vs. Temperature



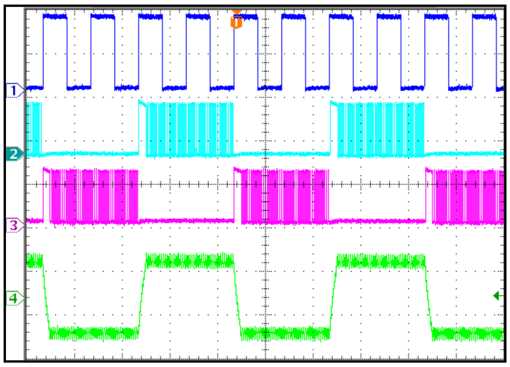
TYPICAL PERFORMANCE CHARACTERISTICS

VIN = 24V, I_{OUT} = 2.5A, F_{STEP} = 1kHz, T_A = 25°C, resistor + inductor load: R = 3.3Ω, L = 1.5mH/channel, unless otherwise noted.

Steady State, Full Step

I_{OUT} = 2A

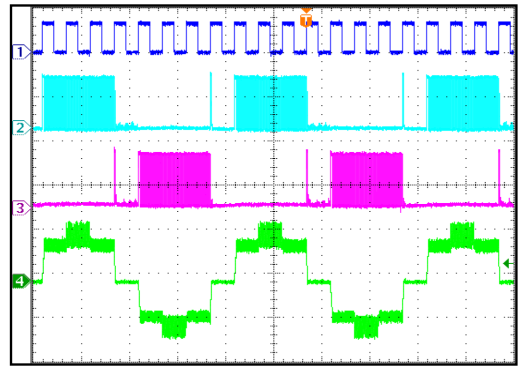
CH1: STEP
2V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div.



1ms/div.

Steady State, Half Step

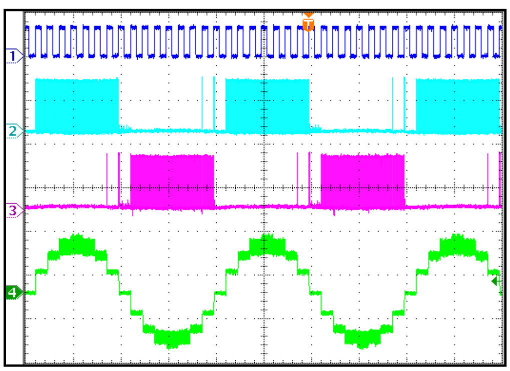
CH1: STEP
5V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div.



2ms/div.

Steady State, Quarter Step

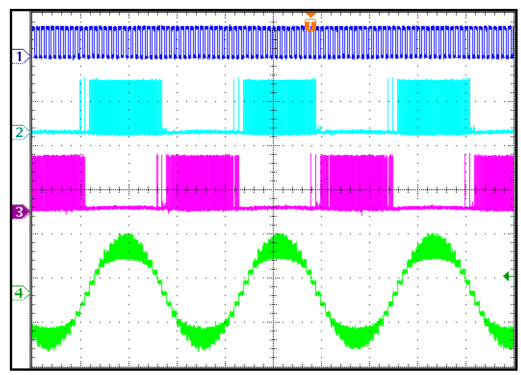
CH1: STEP
5V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div..



4ms/div.

Steady State, Eighth Step

CH1: STEP
5V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div.

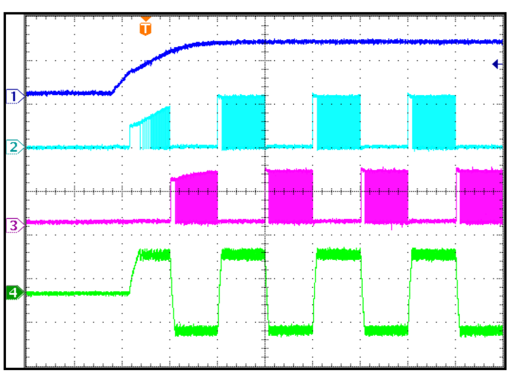


10ms/div.

Power Ramp-Up, Full Step

I_{OUT} = 2A

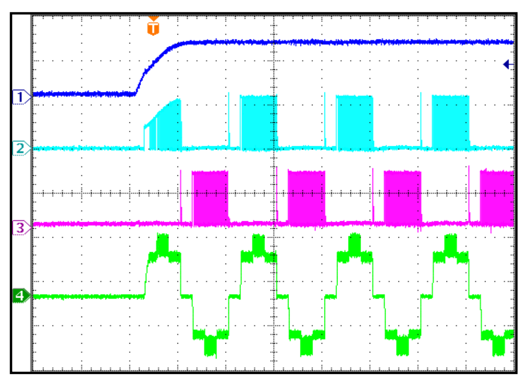
CH1: V_{IN}
20V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div



2ms/div.

Power Ramp-Up, Half Step

CH1: V_{IN}
20V/div.
CH2: A_{OUT1}
20V/div.
CH3: A_{OUT2}
20V/div.
CH4: I_{OUTA}
2A/div

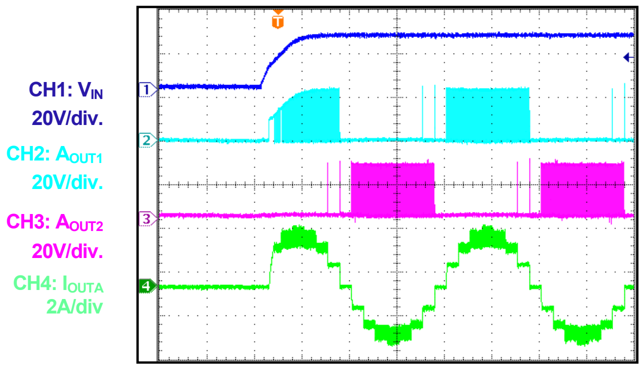


4ms/div.

TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

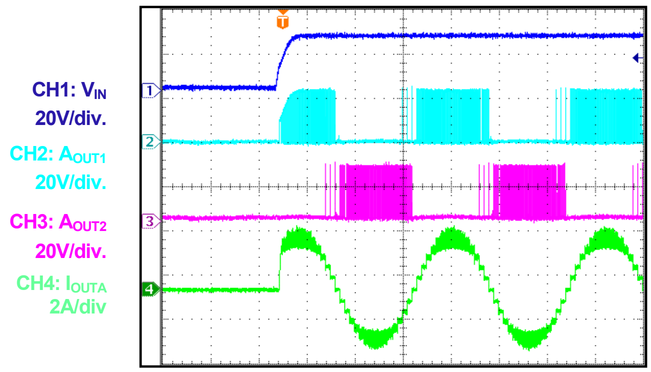
VIN = 24V, I_{OUT} = 2.5A, F_{STEP} = 1kHz, T_A = 25°C, resistor + inductor load: R = 3.3Ω, L = 1.5mH/channel, unless otherwise noted.

Power Ramp-Up, Quarter Step



4ms/div.

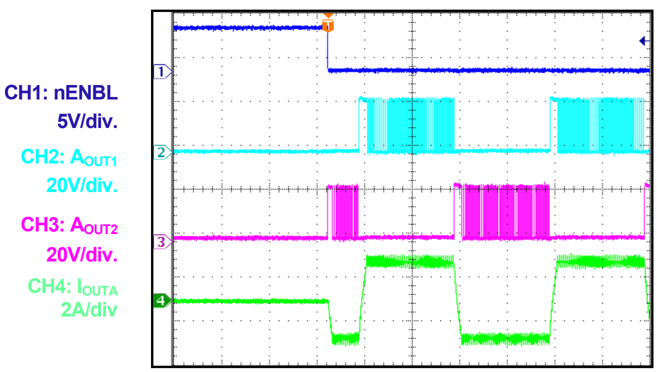
Power Ramp-Up, Eighth Step



10ms/div.

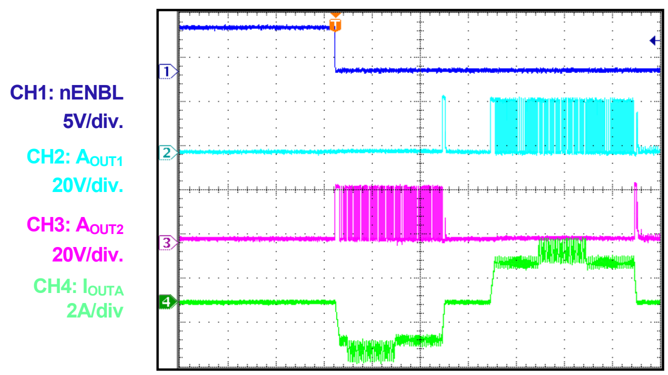
Enable, Full Step

I_{OUT} = 2A



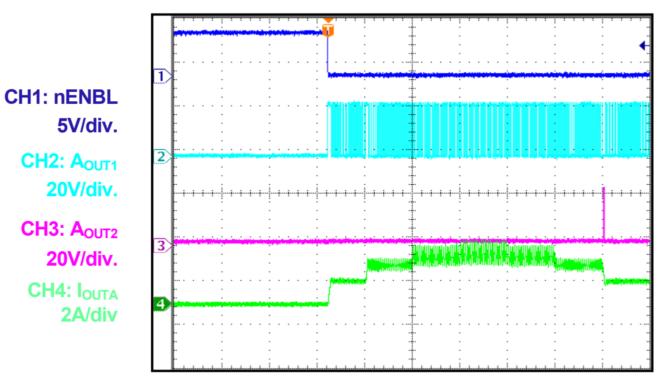
1ms/div.

Enable, Half Step



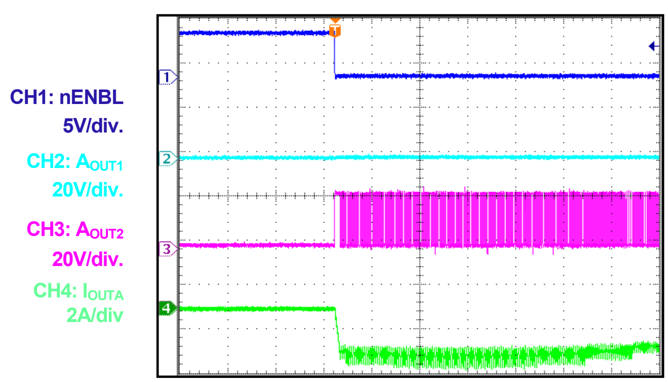
1ms/div.

Enable, Quarter Step



1ms/div.

Enable, Eighth Step



1ms/div.

PIN FUNCTIONS

Pin # QFN	Pin # TSSOP	Name	Description
1	11	DIR	**Direction input.** DIR has an internal pull-down resistor.
2	12	nFAULT	**Fault indication.** nFAULT is an open-drain output. Drive nFAULT to logic low when in a fault condition (OCP, OTP, OVP).
3	13	ISET	**Current set programming.** A resistor from ISET to ground sets the current through the motor.
4	14	AGND	**Analog ground.**
5	15	ROSC	**Constant off-time programming.** A resistor from ROSC to ground sets the PWM off time.
6	16	MS2	**Mode selection.** MS1 and MS2 set the step mode (full, 1/2, 1/4, or 1/8 step). MS1 and MS2 have an internal pull-down resistor.
7	18	MS1	
8, 12, 20, 24, EP	6, 10, 19, 23, EP	GND	**Power ground.**
9	20	BOUT1	**Bridge B output terminal 1.**
10, 22	8, 21	VIN	**Input supply voltage.** Both VIN pins must be connected to the same supply. Decouple VIN to ground with a minimum 100nF ceramic capacitor.
11	22	BOUT2	**Bridge B output terminal 2.**
13	24	STEP	**Step input.** The rising edge sequences the translator and advances the motor by one increment. STEP has an internal pull-down resistor.
14	25	VCP	**Charge pump output.** VCP requires a 1µF, 16V, ceramic capacitor to VIN.
15	28	CP2	**Charge pump capacitor.** Connect a 100nF ceramic capacitor rated for the VIN voltage between these terminals.
16	1	CP1	
17	2	VG	**Low-side MOSFETs gate drive voltage.** VG requires a 220nF, 16V, ceramic capacitor to ground.
-	3, 17, 26, 27	NC	**No connection.**
18	4	nENBL	**Enable input.** Drive nENBL to logic high to disable the bridge outputs and translator operation. Drive nENBL to logic low to enable the bridge outputs and translator operation. nENBL has an internal pull-down resistor.
19	5	nSLEEP	**Sleep mode input.** Drive nSLEEP to logic high to enable normal operation. nSLEEP has an internal pull-down resistor .
21	7	AOUT2	**Bridge A output terminal 2.**
23	9	AOUT1	**Bridge A output terminal 1.**

BLOCK DIAGRAM

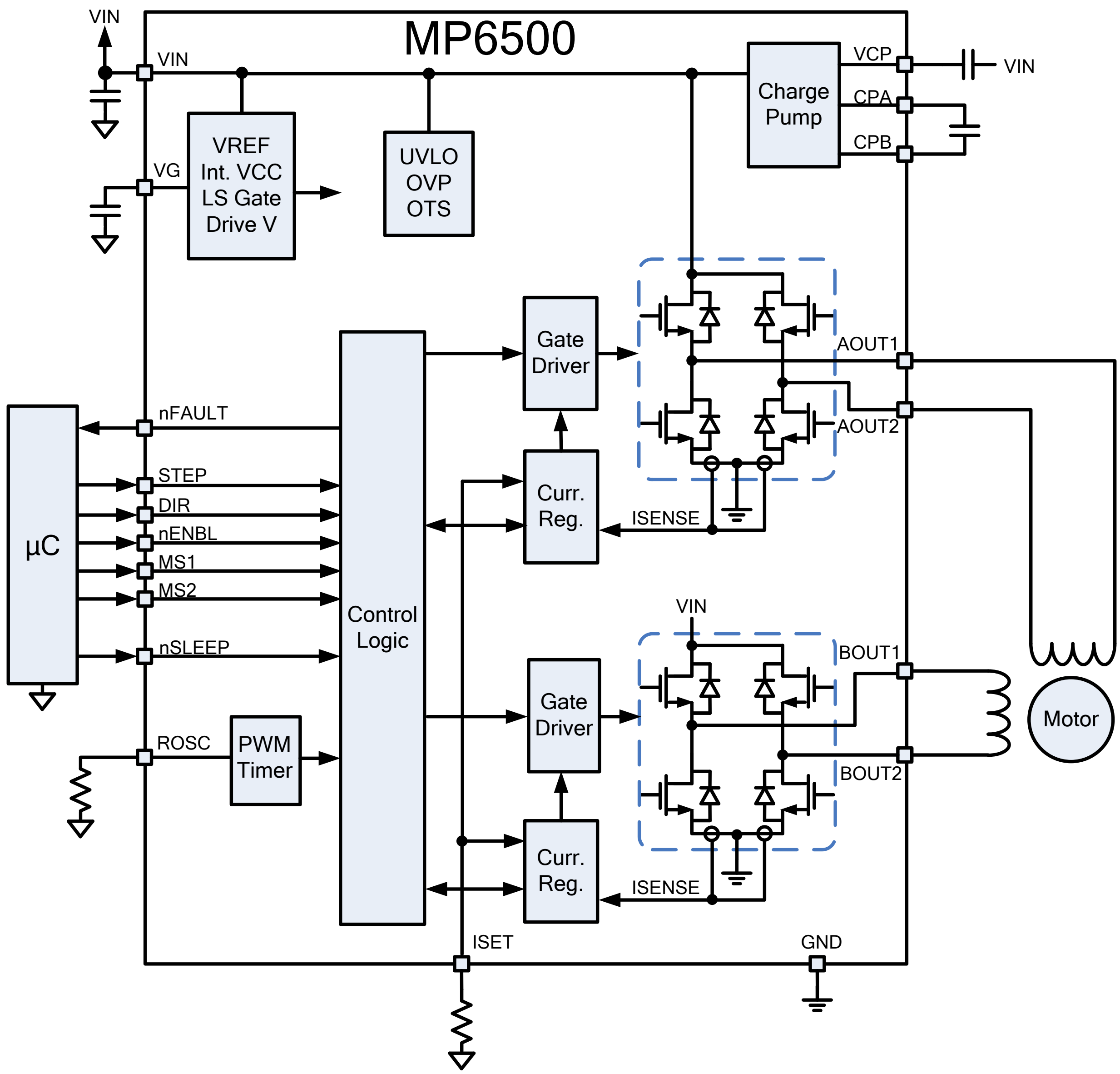


Figure 1: Functional Block Diagram

OPERATION

The MP6500 is a bipolar, stepper motor driver that integrates eight N-channel power MOSFETs arranged as two full-bridges with 2.5A of current capability each. The MP6500 operates over a wide 4.5V to 35V supply voltage range.

The MP6500 is designed to operate bipolar stepper motors in full-, half-, quarter-, and eighth-step modes. At each step, the current of each full-bridge is set by the output voltage of a DAC, which is controlled by the output of the translator.

The currents in each of the two outputs are regulated with programmable, constant off-time, pulse-width modulation (PWM) control circuitry. The MP6500 integrates internal current sensing with no external sense resistors required.

Stepping

The motor moves step-by-step by applying a series of pulses to STEP. A rising edge on the STEP input sequences the translator and advances the motor by one increment. The translator controls the input to the DACs and the direction of current flow in each winding. The amplitude of the increment (step size) is determined by the state of the inputs (MS1 and MS2) (see Table 1).

The state of DIR determines the direction of the rotation of the stepper motor.

The minimum STEP pulse width is 1µs. The logic control inputs MSx and DIR require at least 200ns of set-up time and hold time to the rising edge of the STEP input (see Figure 2).

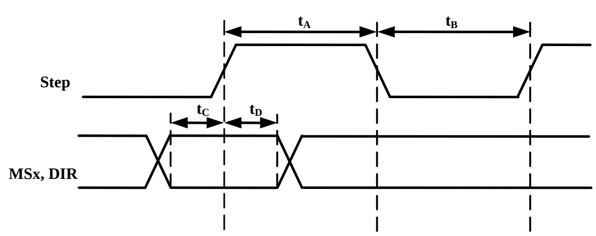


Figure 2: STEP Timing Diagram

Programmable Constant Off-Time Current Control

The motor current is regulated by a programmable constant off-time PWM current control circuit.

Initially, a diagonal pair of MOSFETs turns on and drives current through the motor winding. The current increases in the motor winding, which is sensed by an internal current sense circuit. During the initial blanking time (t_{BLANK}), the high-side MOSFET (HS-FET) always turns on in spite of current limit detection.

When the current reaches the current trip threshold, the internal current comparator either shuts off the HS-FET so the winding inductance current freewheels through the two low-side MOSFETs (LS-FET) (slow decay) or turns on another diagonal pair of MOSFETs so the current flows back to the input (fast decay). The current continues decreasing for the constant off-time duration unless a zero current level is detected. Afterward, the HS-FET is enabled to increase the winding current again. The cycle then repeats.

The constant off-time (t_{off}) is determined by the selection of an external resistor (R_{OSC}), which can be approximated with Equation (1):

$$t_{OFF}(ns) = 115 \times R_{OSC}(k\Omega) \quad (1)$$

The full-scale (100%) regulation current can be calculated with Equation (2):

$$I_{Max} = 78k\Omega / R_{ISET} \quad (2)$$

The DAC output reduces the trip current in precise steps. Calculate the trip current with Equation (3):

$$I_{Trip} = \%I_{Trip} \times I_{Max} \quad (3)$$

See Table 2 for $\%I_{Trip}$ at each step.

Blanking Time

There is usually a current spike during the switching transition due to the body diode's reverse-recovery current and the distributed winding capacitance of the motor. This current spike requires filtering to prevent it from erroneously shutting down the HS-FET.

After the PWM cycle begins, the output of the current sense comparator is ignored for the fixed blanking time. This blanking time results in a minimum on time for the PWM cycle.

Automatic Decay Mode

The MP6500 uses a fully automatic decay mode to provide accurate current regulation.

Initially, slow decay is used. At the end of the fixed off time, if the current is above the I_{TRIP} threshold, then fast decay mode is initiated by reversing the state of the H-bridge outputs.

Once the current level during this fast decay period drops below the I_{TRIP} threshold, slow decay is again engaged for another fixed off time. After the completion of this second fixed off time, a new PWM cycle begins.

Figure 3 below shows the automatic decay mode operation during a current reduction as a result of a step input.

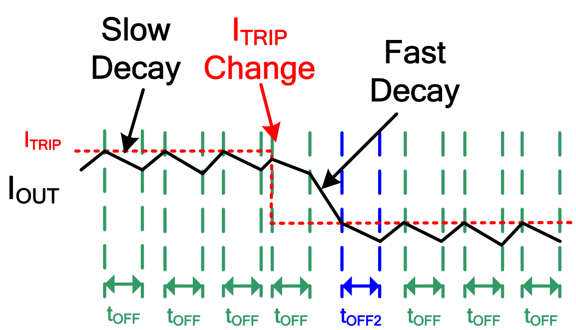


Figure 3: Slow Decay During t_{OFF} unless I_{OUT} > I_{TRIP} at end of t_{OFF}

In some cases, specifically high voltage and low inductance or the regulation of very small currents, the minimum on time of the PWM cycle (set by the blanking time described above) can cause the current to rise very quickly. In this case, both slow and fast decay are used (see Figure 4).

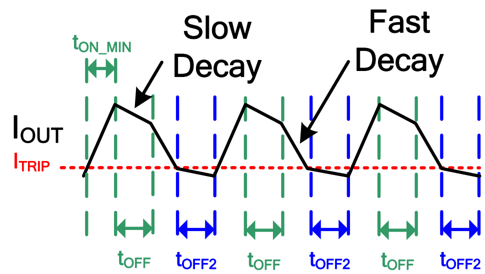


Figure 4: Current Regulation of Low Current/Low Inductance

Microstep Selection (MS1, MS2)

The step mode is selected by applying logic high and low voltages to the MS1 and MS2 (see Table 1). The MP6500 supports full-, half-, quarter-, and eighth-step modes for progressively finer step resolution and control.

Table 1: Stepping Format

MS2	MS1	STEP Mode
L	L	Full step
L	H	Half step
H	L	Quarter step
H	H	Eighth step

Full-step mode has four states with each motor winding driven with either 70.7% of the maximum positive current or 70.7% of the maximum negative current. This provides four steps per electrical rotation. Half-step mode creates eight steps per electrical rotation. Quarter- and eighth-step modes provide 16 and 32 steps per rotation respectively.

Table 2 and Figure 5 show the relative current level sequence for different settings of MSx.

The MSx pins have internal pull-down resistors.

SLEEP, nENBL Operation

Driving nSLEEP low puts the device into a low-power sleep state. In this state, the gate drive charge pump is stopped, and all the internal circuits and H-bridge outputs are disabled. All inputs are ignored when nSLEEP is active low.

When waking up from sleep mode, approximately 1ms of time must pass before a STEP command can be issued to allow the internal circuitry to stabilize. nSLEEP has an internal pull-down resistor.

The nENBL pin is used to control the output drivers. When nENBL is low, the output H-bridge outputs are enabled, and the rising edges on STEP are recognized. When nENBL is high, the H-bridge outputs are disabled, and the STEP input is ignored. nENBL has an internal pull-down resistor.

Fault Reporting

The MP6500 provides an nFAULT pin, which reports if a fault condition (such as OCP, OTP, or OVP) occurs. nFAULT is an open-drain output and is driven low when a fault condition occurs. If the fault condition is removed, nFAULT is pulled high by an external pull-up resistor.

Over-Current Protection (OCP)

Over-current protection (OCP) circuitry limits the current through the MOSFETs by disabling the gate driver. If the over-current limit threshold is exceeded for longer than the over-current deglitch time, all MOSFETs in the H-bridge are disabled, and nFAULT is driven low. The driver remains disabled for 2.4ms typically, at which time it is re-enabled automatically.

Over-current conditions on both high- and low-side devices (i.e.: a short to ground, supply, or across the motor winding) result in an over-current shutdown. Note that OCP does not use the current sense circuitry used for PWM current control.

Over-Voltage Protection (OVP)

If the input voltage on VIN is higher than the over-voltage protection (OVP) threshold, the H-bridge output is disabled, and nFAULT is driven low. This protection is released when VIN drops below 36V.

Input Under-Voltage Lockout (UVLO) Protection

If at any time the voltage on VIN falls below the under-voltage lockout (UVLO) threshold voltage, all circuitry in the device is disabled, and the internal logic is reset. Operation resumes when VIN rises above the UVLO threshold.

Thermal Shutdown

If the die temperature exceeds safe limits, all MOSFETs in the H-bridge are disabled, and nFAULT is driven low. Once the die temperature has fallen to a safe level, operation resumes automatically.

MICROSTEPPING

Table 2: Relative Current Level Sequence

Eighth Step #	Quarter Step #	Half Step #	Full Step #	Phase A Current %$I_{Trip-LIMIT}$ (%)	Phase B Current %$I_{TRIP-LIMIT}$ (%)	Step Angle (°)
1	1	1		100.00	0.00	0.0
2				98.08	19.51	11.3
3	2			92.39	38.27	22.5
4				83.15	55.56	33.8
5	3	2	1	70.71	70.71	45.0
6				55.56	83.15	56.3
7	4			38.27	92.39	67.5
8				19.51	98.08	78.8
9	5	3		0.00	100.00	90.0
10				-19.51	98.08	101.3
11	6			-38.27	92.39	112.5
12				-55.56	83.15	123.8
13	7	4	2	-70.71	70.71	135.0
14				-83.15	55.56	146.3
15	8			-92.39	38.27	157.5
16				-98.08	19.51	168.8
17	9	5		-100.00	0.00	180.0
18				-98.08	-19.51	191.3
19	10			-92.39	-38.27	202.5
20				-83.15	-55.56	213.8
21	11	6	3	-70.71	-70.71	225.0
22				-55.56	-83.15	236.3
23	12			-38.27	-92.39	247.5
24				-19.51	-98.08	258.8
25	13	7		0.00	-100.00	270.0
26				19.51	-98.08	281.3
27	14			38.27	-92.39	292.5
28				55.56	-83.15	303.8
29	15	8	4	70.71	-70.71	315.0
30				83.15	-55.56	326.3
31	16			92.39	-38.27	337.5
32				98.08	-19.51	348.8

MICROSTEPPING *(continued)*

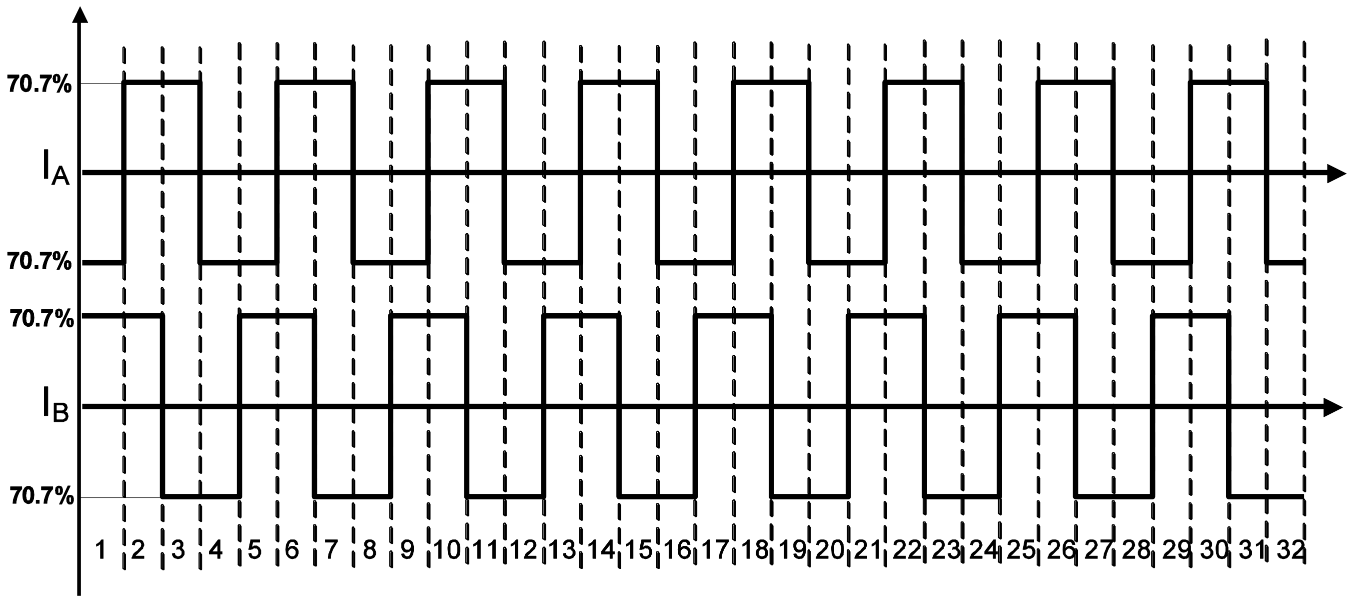


Figure 5a: Full Step (4 Step Sequences)

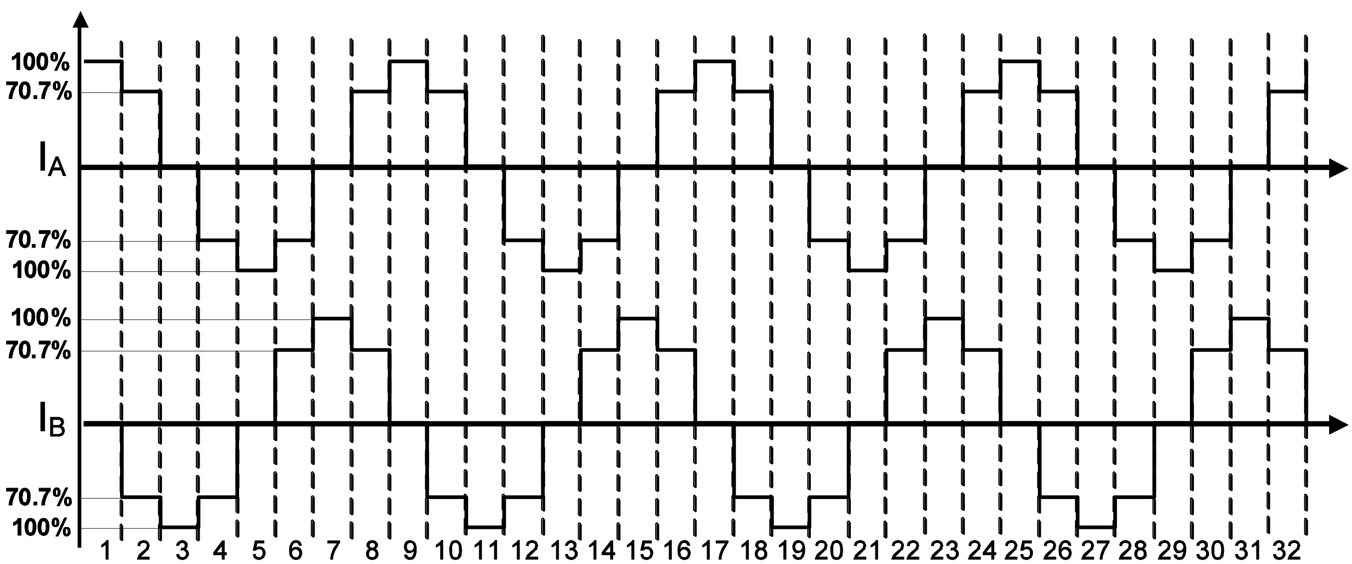


Figure 5b: Half Step (8 Step Sequences)

MICROSTEPPING *(continued)*

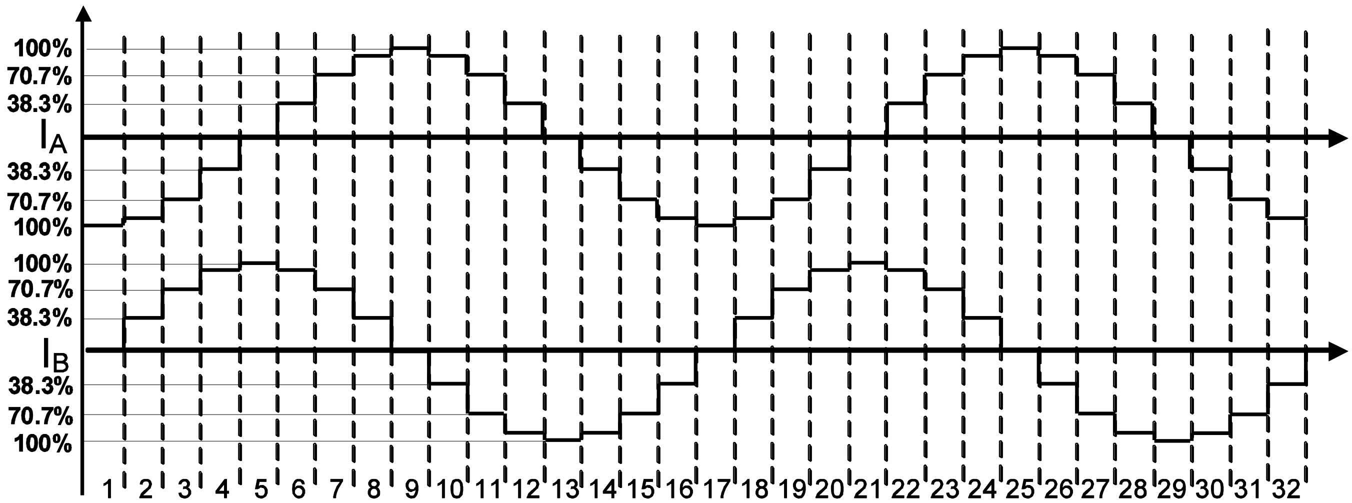


Figure 5c: Quarter Step (16 Step)

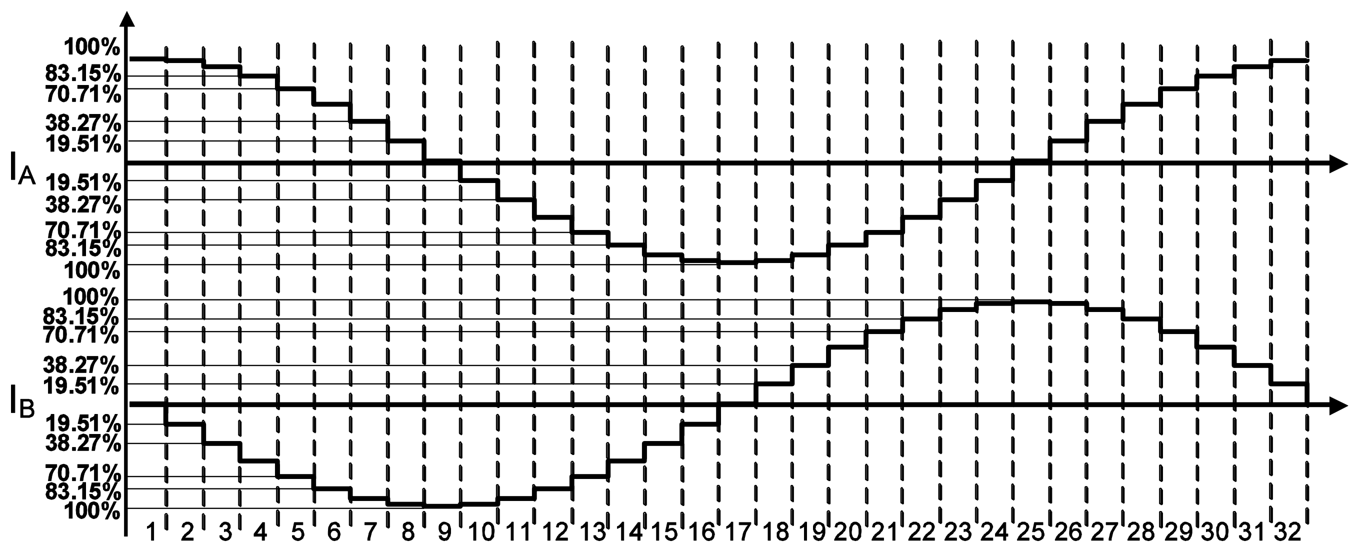
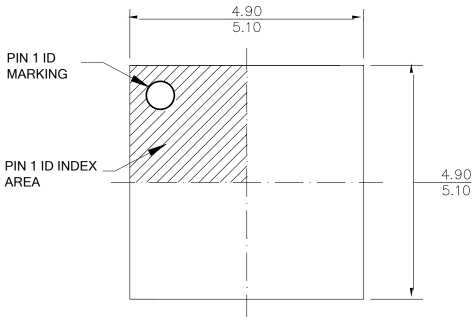


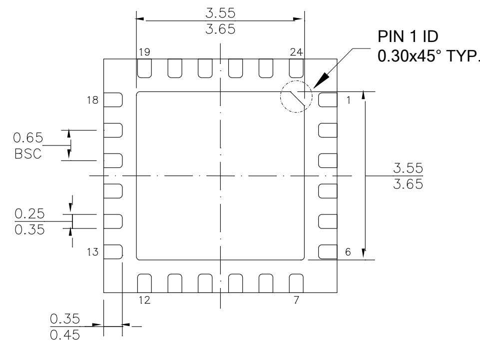
Figure 5d: Eighth Step (32 Step)

PACKAGE INFORMATION

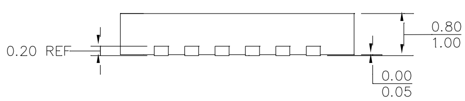
QFN-24 (5mmx5mm)



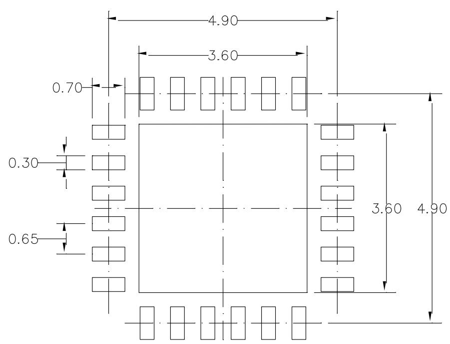
TOP VIEW



BOTTOM VIEW



SIDE VIEW



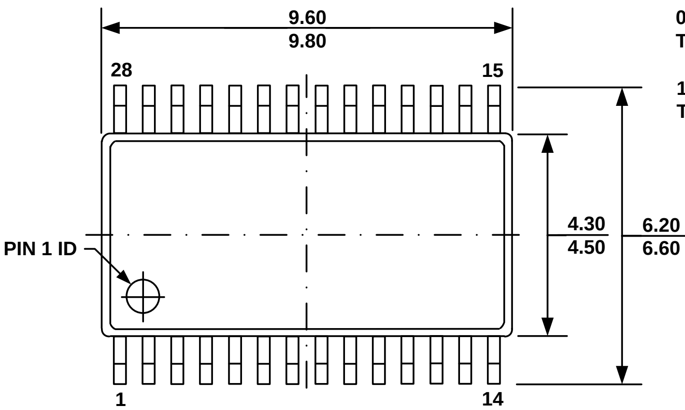
RECOMMENDED LAND PATTERN

NOTE:

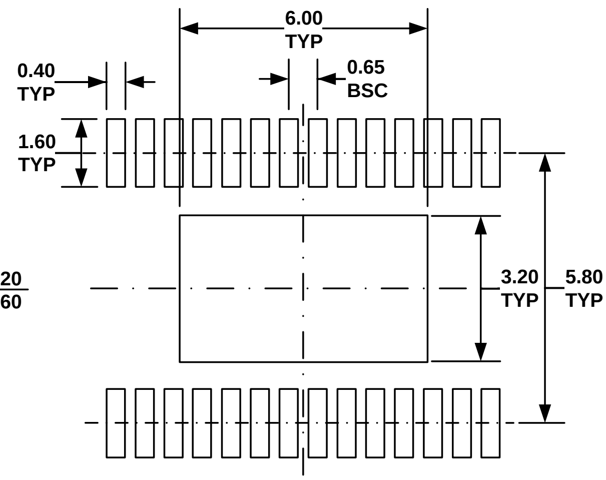
1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
4) DRAWING CONFIRMS TO JEDEC MO-220.
5) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION *(continued)*

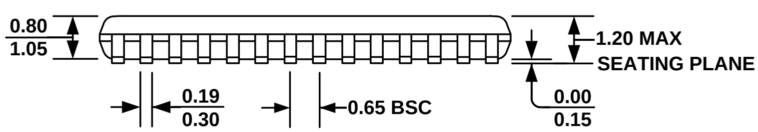
TSSOP-28 EP



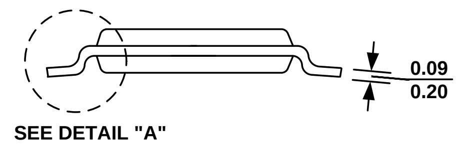
TOP VIEW



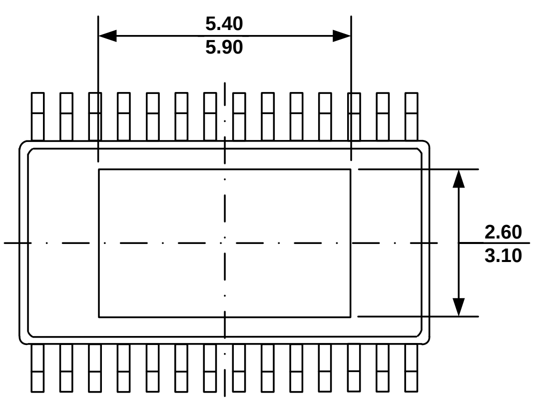
RECOMMENDED LAND PATTERN



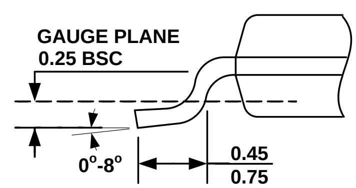
FRONT VIEW



SIDE VIEW



BOTTOM VIEW

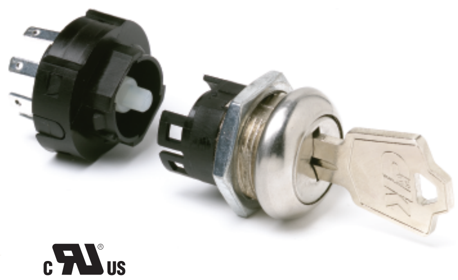


DETAIL "A"

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSION OR GATE BURR.
3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION.
4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.10 MILLIMETERS MAX.
5) DRAWING CONFORMS TO JEDEC MO-153, VARIATION AET.
6) DRAWING IS NOT TO SCALE.

H Series
4 & 6 Tumbler Power Switchlocks



Models Available

Features/Benefits

- ***Positive detent***
- ***Multi-pole and multi-position***
- ***Snap-together assembly***
- ***Power switching***

Typical Applications

- ***Machine controls***
- ***Elevators***

Specifications

CONTACT RATING: Q contact material: 12 AMPS @ 125 V AC; 6 AMPS @ 250 V AC; 1 AMP @ 125 V DC (UL/CSA). See page L-37 for additional ratings.

ELECTRICAL LIFE: 10,000 make-and-break cycles at full load.

CONTACT RESISTANCE: Below 10 m Ω typ. initial @ 2-4 V DC, 100 mA, for both silver and gold plated contacts.

INSULATION RESISTANCE: 10^9 Ω min.

DIELECTRIC STRENGTH: 1,000 Vrms min. @ sea level.

OPERATING TEMPERATURE: –30°C to 85°C.

INDEXING: 45° or 90°, 2-4 Positions.

NOTE: Any models supplied with Q or B contact material are RoHS compliant.

NOTE: Specifications and materials listed above are for switchlocks with standard options. For information on specific and custom switchlocks, consult Customer Service Center.

Materials

LOCK: Zinc alloy with stainless steel facing (4 tumbler locks and 6 tumbler tubular lock).

KEYS: Two nickel plated brass keys with code number (4 tumbler). Two die cast chrome plated zinc alloy keys (6 tumbler).

SWITCH HOUSING: 6/6 nylon (UL 94V-2).

CONTACTS & TERMINALS: Q contact material: Copper, silver plated. See page L-37 for additional contact materials.

CONTACT SPRING: Music wire or stainless steel.

MOUNTING NUT: Zinc alloy.

MOUNTING CLIP: Steel, zinc plated.

DRESS NUT: Brass, nickel plated.

TERMINAL SEAL: Epoxy.

Build-A-Switch

To order, simply select desired option from each category and place in the appropriate box. Available options are shown and described on pages L–35 through L–38. For additional options not shown in catalog, consult Customer Service Center.

Switch and Lock Function
- **H10113** SP, 90º Index, keypull pos.1
- **H2011U** DP, 90º Index, keypull pos. 1 & 2
- **H100AA** SP, 45º Index, keypull pos. 1,2 & 3
- **H200AA** DP, 45º Index, keypull pos. 1, 2 & 3
- **H20113** DP, 90º Index, keypull pos. 1
- **H1011U** SP, 90º Index, keypull pos.1 & 2
- **H1417U** SP, 90º Index, keypull pos. 1,2 & 3

Keying
- **2** Two nickel plated brass keys (4 tumbler) or two die cast zinc alloy keys with chrome plating (6 tumbler)
- **T** One nickel plated brass key with plastic insert molded square head and one nickel plated brass key

Lock Type
- **F** 4 Tumbler lock with detent
- **V** 6 Tumbler tubular lock

Lock Finish
- **2** Stainless steel facing
- **8** Gloss black facing

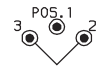
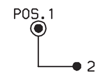
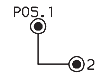
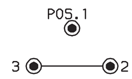
Terminations
- **05** Quick connect
- **WC** Wire lead

Mounting/Lock Style
- **N** With nut
- **D** With clip

Contact Material
- **Q** Silver
- **B** Gold

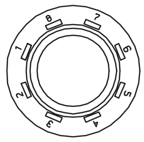
Key Color
- **NONE** Nickel plated brass (4 tumbler) or chrome plated zinc alloy (6 tumbler)
- **2** Black

SWITCH AND LOCK FUNCTION

NO. TUMBLERS	NO. POLES	MODEL NO.	CONNECTED TERMINALS POS. 1	POS. 2	POS. 3	POS. 4	KEY PULL POSITIONS	LOCK CONFIGURATION	INDEXING
4	SP DP	H100AA H200AA	7-8 7-8, 3-4	8-1 8-1, 4-5	6-7 6-7, 2-3		Positions 1, 2 & 3		45°
4 & 6	SP DP	H10113 H20113	7-8 7-8, 3-4	8-2 8-2, 4-6			Position 1		90°
4 & 6	SP DP	H1011U H2011U	7-8 7-8, 3-4	8-2 8-2, 4-6			Positions 1 & 2		90°
4	SP	H1417U	6-8	8-2	5-6		Positions 1, 2 & 3		90°

All models cULus with all options when ordered with ‘G’ or ‘Q’ contact material.

TERMINAL NUMBERS



Terminal numbers molded on housing.

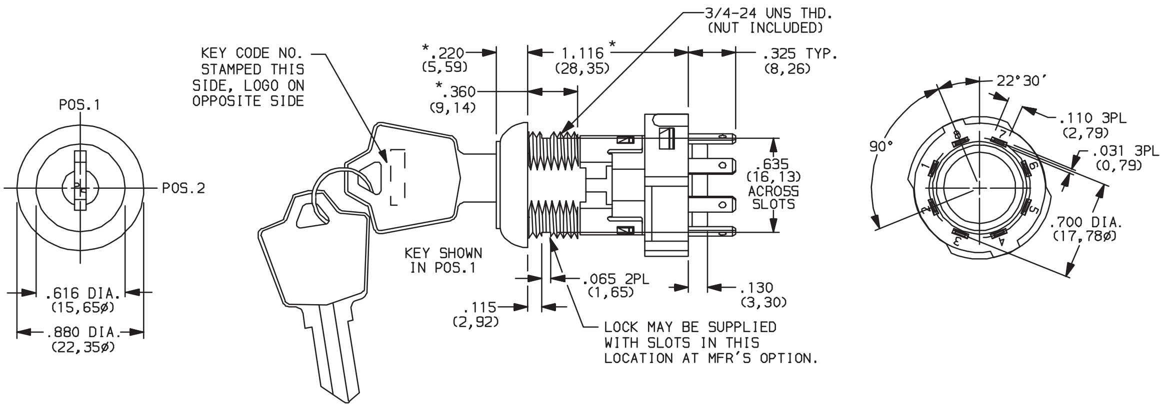
LEGEND

● = Detent Positions (45° or 90°)

◉ = Key pull possible in these positions.

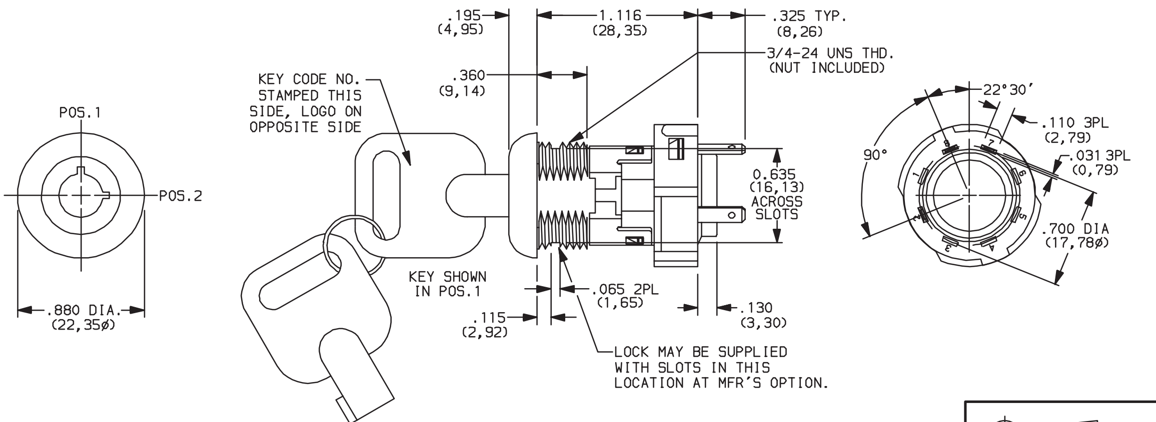
◉ = Stop Positions

4 Tumbler

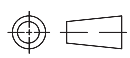


Part number shown: H101132F205NQ

6 Tumbler



Part number shown: H1011U2V205NQ



Third Angle Projection

Dimensions are shown: Inch (mm)
Specifications and dimensions subject to change

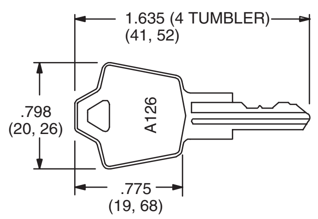
KEYING

OPTION CODE	KEY OPTIONS	CODE NO. ON KEY	CODE NO. ON LOCK
2	2 NICKEL PLATED BRASS KEYS (4 TUMBLER) OR 2 CHROME PLATED ZINC ALLOY KEYS (6 TUMBLER)	YES	NO
T	1 NICKEL PLATED BRASS KEY WITH PLASTIC INSERT MOLDED SQUARE HEAD & 1 NICKEL PLATED BRASS KEY	YES	NO

OPTION CODE	KEY COLOR
NONE	NICKEL PLATED BRASS (4 TUMBLER) OR CHROME PLATED ZINC ALLOY (6 TUMBLER)
2	BLACK

NOTE: All orders keyed alike, standard. For more than one key code, replacement keys, or other special features, consult Customer Service Center.

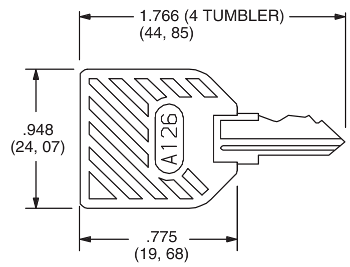
NICKEL PLATED BRASS KEY



Key part number: 115140126

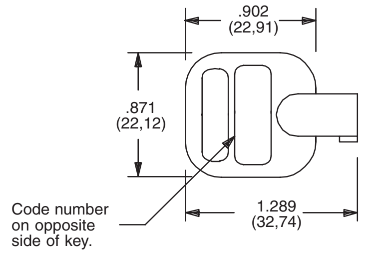
NOTE: Key head shape subject to change without notice.

NICKEL PLATED BRASS KEY WITH PLASTIC INSERT MOLDED SQUARE HEAD



Key part number: 11599112602

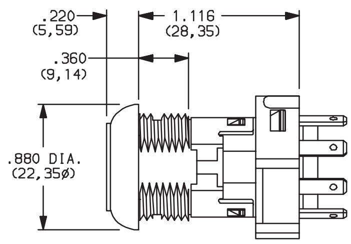
CHROME PLATED ZINC ALLOY KEY



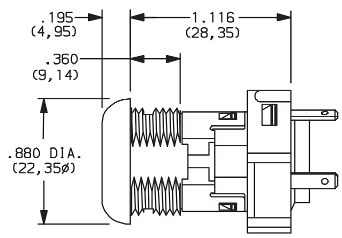
Key part number: 363C1AAAA

LOCK TYPE

F 4 TUMBLER LOCK WITH ADDED DETENT



V 6 TUMBLER TUBULAR LOCK



LOCK FINISH

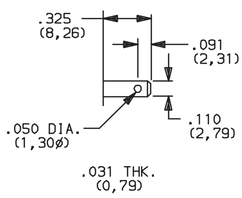
2 STAINLESS STEEL FACING

Available with
V lock type only.

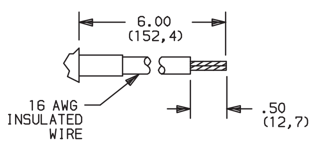
8 GLOSS BLACK FACING

TERMINATIONS

05 .110" QUICK CONNECT



WC WIRE LEAD



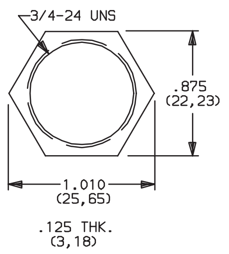
Black wire standard, other colors, gages and lengths available, consult Customer Service Center. UL style 1015.

Third Angle Projection

Dimensions are shown: Inch (mm)
Specifications and dimensions subject to change

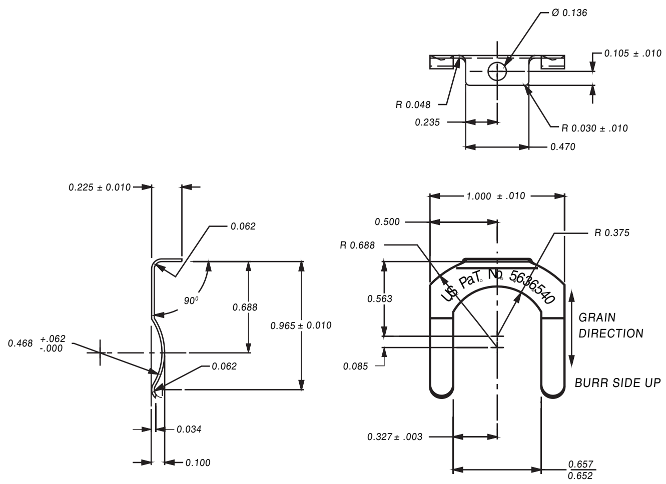
MOUNTING/LOCK STYLE

N WITH NUT



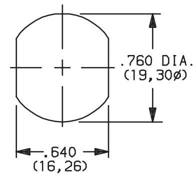
Nut part number: 937C00000

D WITH CLIP



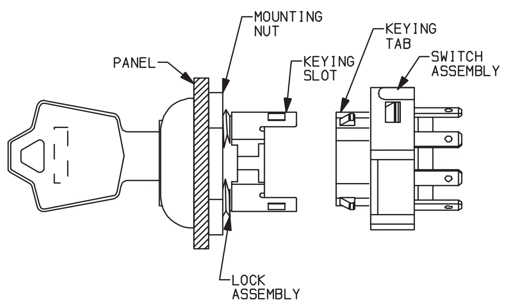
Clip part number: 906B00000

PANEL MOUNTING



MOUNTING STYLES	PANEL THICKNESS
D	.065-.085 (1,65-2,16)
N	.195 (4,95) max.

Switch and Lock Assembly Instructions



1. Place lock assembly in mounting hole on panel, secure with mounting nut.
2. Align keying tab on switch assembly with keying slot on lock assembly.
3. Snap assemblies together.
4. Switch installation is permanent. Switch cannot be removed from lock after assembly. Attempting to separate switch and lock may cause damage to switchlock.

CONTACT MATERIAL

OPTION CODE	RoHS COMPLIANT*	RoHS COMPATIBLE*	CONTACT AND TERMINAL MATERIAL	RATING	
Q	YES	YES	SILVER [2]	POWER	12 AMPS @ 125 V AC; 6 AMPS @ 250 V AC; 1 AMP @ 125 V DC (UL/CSA).
B	YES	YES	GOLD [1]	LOW LEVEL/DRY CIRCUIT	0.4 VA MAX. @ 20 V AC or DC MAX.

[1] CONTACTS & TERMINALS: Copper, with gold plate over nickel plate.
[2] CONTACTS & TERMINALS: Copper, silver plated.

* Note: See Technical Data section of this catalog for RoHS compliant and compatible definition and specifications.

All models c UL us with all options when ordered with 'Q' contact material.

Third Angle Projection

Dimensions are shown: Inch (mm)
Specifications and dimensions subject to change

AVAILABLE HARDWARE

Key Code: A126
4 TUMBLER
PART NO. (ONE KEY)
115140126
Material: Brass
Finish: Nickel plate

Key Code: AAAA
PART NO. (ONE KEY)
363C1AAAA
Material: Zinc Alloy
Finish: Chrome plate

Key Code: A126
4 TUMBLER
PART NO. (ONE KEY)
1159112602 BLACK
Material: Brass
Finish: Nickel plate
6/6 Nylon insert molded head

Third Angle Projection
Dimensions are shown: Inch (mm)
Specifications and dimensions subject to change

Mouser Electronics

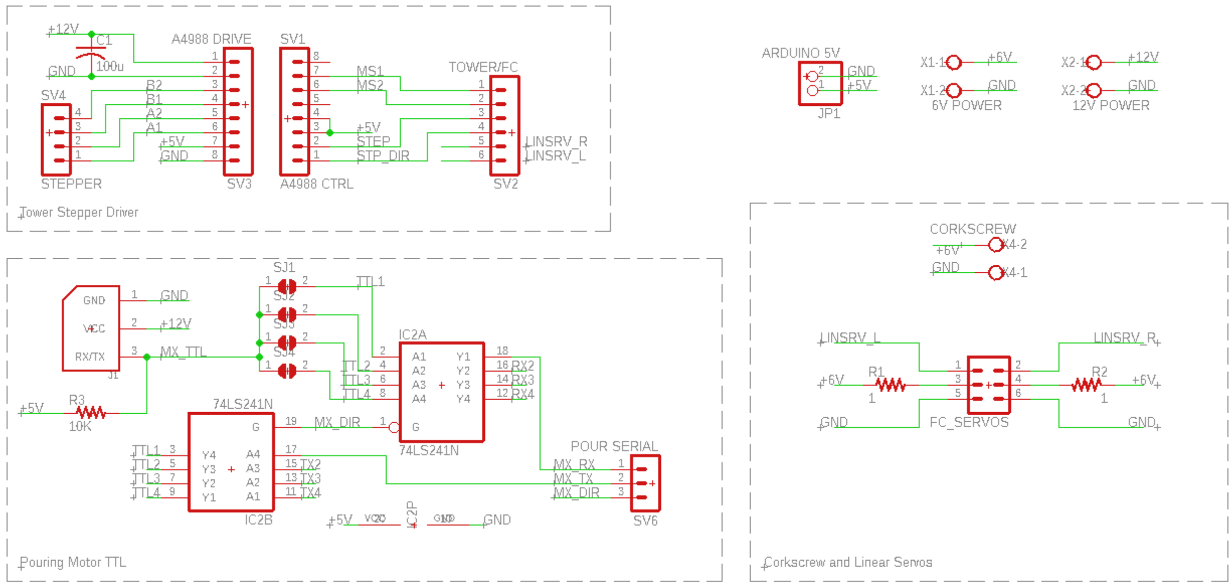
Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

C&K Switches:

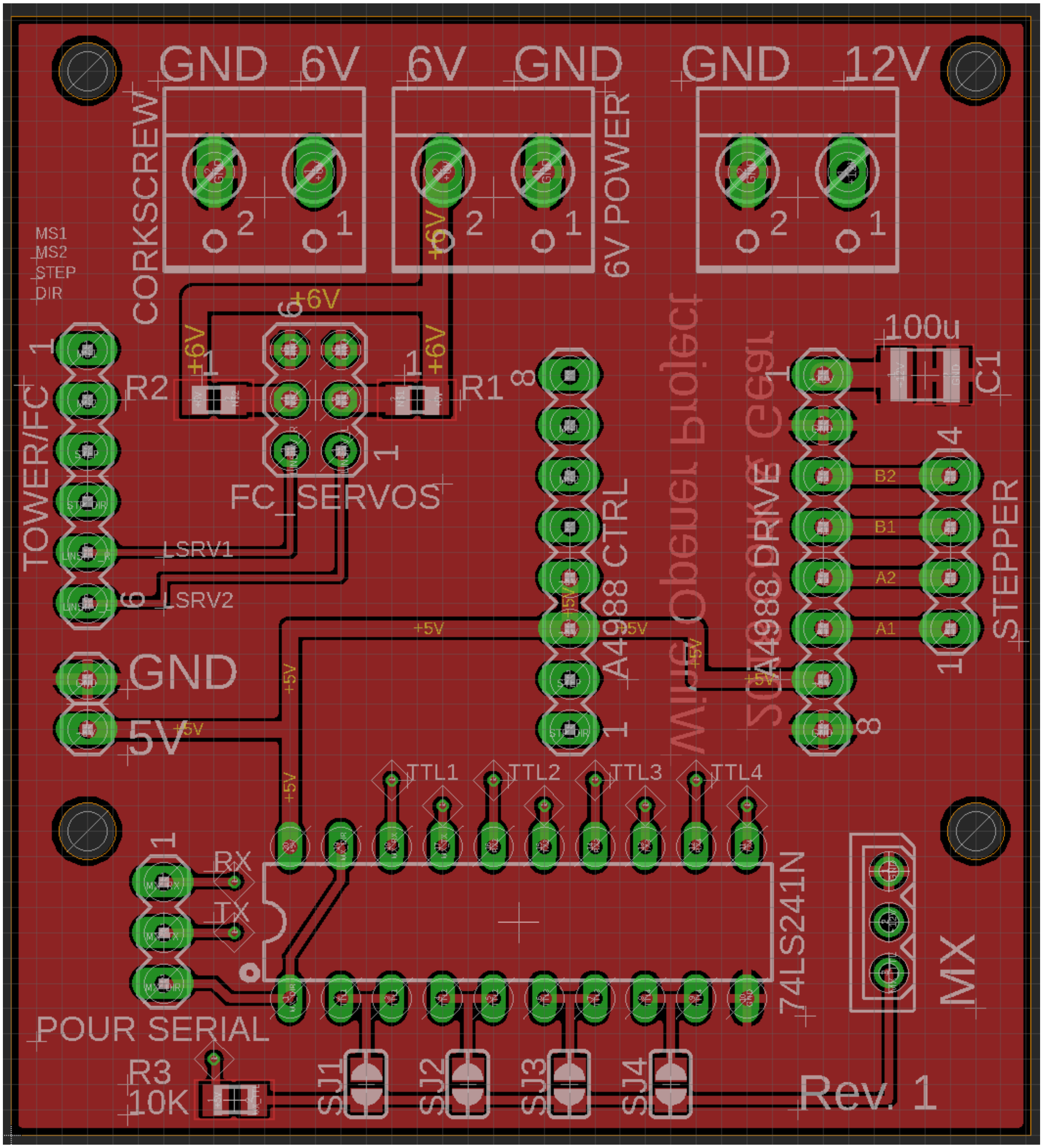
H201132F205NQ H100AA2F205NQ H101132F205NQ H101132F2WCNQ H1011U2F205NQ H1011U2F805NQ H200AA2F205NQ H2011U2F205NQ H101132F205NB H200AA2F205NB H10113TF805NQ2 H1417U2F805DB H101132V205NQ

WINE OPENER P/N: B616



Rev. 1:
- Added 10K pullup resistor between MX_TTL and +5V
- Changed stepper driver module headers from MP6500 to A4988
- Board ground plane Isolation distance increased

WINE OPENER P/N: B616



WINE OPENER
P/N: B617

SDLS144D – APRIL 1985 – REVISED OCTOBER 2016

SNx4LS24x, SNx4S24x Octal Buffers and Line Drivers With 3-State Outputs

1 Features

- Inputs Tolerant Down to 2 V, Compatible With 3.3-V or 2.5-V Logic Inputs
- Maximum t_{pd} of 15 ns at 5 V
- 3-State Outputs Drive Bus Lines or Buffer Memory Address Registers
- PNP Inputs Reduce DC Loading
- Hysteresis at Inputs Improves Noise Margins

2 Applications

- Servers
- LED Displays
- Network Switches
- Telecom Infrastructure
- Motor Drivers
- I/O Expanders

3 Description

The SNx4LS24x, SNx4S24x octal buffers and line drivers are designed specifically to improve both the performance and density of three-state memory address drivers, clock drivers, and bus-oriented receivers and transmitters. The designer has a choice of selected combinations of inverting and non-inverting outputs, symmetrical, active-low output-control ($\overline{G}$) inputs, and complementary output-control (G and $\overline{G}$) inputs. These devices feature high fan-out, improved fan-in, and 400-mV noise margin. The SN74LS24x and SN74S24x devices can be used to drive terminated lines down to 133 Ω.

Device Information[(1)]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
SN54LS24x, SN54S24x	CDIP (20) – J	24.20 mm × 6.92 mm
	CFP (20) – W	7.02 mm × 13.72 mm
	LCCC (20) – FK	8.89 mm × 8.89 mm
SN74LS240, SN74LS244	SSOP (20) – DB	7.20 mm × 5.30 mm
SN74LS24x, SN74S24x	SOIC (20) – DW	12.80 mm × 7.50 mm
	PDIP (20) – N	24.33 mm × 6.35 mm
SN74LS24x	SOP (20) – NS	7.80 mm × 12.60 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Logic Diagram (Positive Logic)

‘LS240, ‘S240

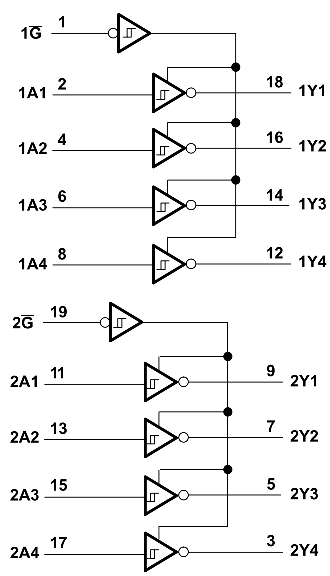


Table of Contents

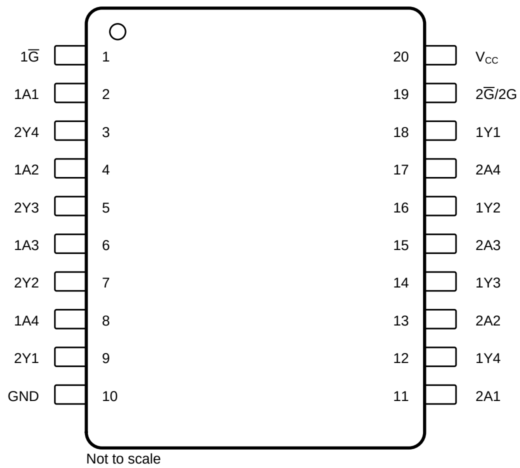
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

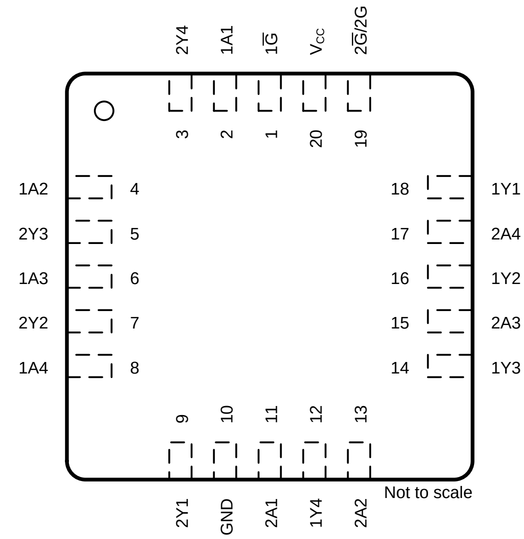
Changes from Revision C (May 2010) to Revision D	Page
• Added *Applications* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section	1
• Deleted Ordering Information table; see POA at the end of the data sheet	1
• Changed $R\theta_{JA}$ values in the *Thermal Information* table from 70 to 94.3 (DB), from 58 to 90.3 (DW), from 69 to 50.6 (N), and from 60 to 76.6 (NS)	5

5 Pin Configuration and Functions

DB, DW, J, N, NS, or W Package
20-Pin SSOP, SOIC, CDIP, PDIP, SOP, or CFP
Top View



FK Package
20-Pin LCCC
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	$1\overline{G}$	I	Channel 1 output enable
2	1A1	I	Channel 1, A side 1
3	2Y4	O	Channel 2, Y side 4
4	1A2	I	Channel 1, A side 2
5	2Y3	O	Channel 2, Y side 3
6	1A3	I	Channel 1, A side 3
7	2Y2	O	Channel 2, Y side 2
8	1A4	I	Channel 1, A side 4
9	2Y1	O	Channel 2, Y side 1
10	GND	—	Ground
11	2A1	I	Channel 2, A side 1
12	1Y4	O	Channel 1, Y side 4
13	2A2	I	Channel 2, A side 2
14	1Y3	O	Channel 1, Y side 3
15	2A3	I	Channel 2, A side 3
16	1Y2	O	Channel 1, Y side 2
17	2A4	I	Channel 2, A side 4
18	1Y1	O	Channel 1, Y side 1
19	$2\overline{G}$/2G [(1)]	I	Channel 2 output enable
20	V_{CC}	—	Power supply

(1) 2G for SNx4LS241 and SNx4S241 or $2\overline{G}$ for all other drivers.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Supply voltage, V_{CC} (2)			7	V
Input voltage, V_I	SNx4LS24x		7	V
	SNx4S24x		5.5	
Off-state output voltage			5.5	V
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Voltage values are with respect to network ground terminal.

6.2 ESD Ratings

			VALUE	UNIT
ALL PACKAGES				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	500	V
N PACKAGE				
$V_{(ESD)}$	Electrostatic discharge	Charged device model (CDM), per JEDEC specification JESD22-C101 (2)	500	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage (1)	SN54xS24x	4.5	5	5.5	V
		SN74xS24x	4.75	5	5.25	
V_{IH}	High-level input voltage		2			V
V_{IL}	Low-level input voltage	SN54LS24x			0.7	V
		SN54S24x, SN74xS24x			0.8	
I_{OH}	High-level output current	SN54xS24x			–12	mA
		SN74xS24x			–15	
I_{OL}	Low-level output current	SN54LS24x			12	mA
		SN54S24x			48	
		SN74LS24x			24	
		SN74S24x			64	
	External resistance between any input and V_{CC} or ground (SNx4S24x only)				40	kΩ
T_A	Operating free-air temperature (2)	SN54xS24x	–55		125	°C
		SN74xS24x	0		70	

(1) Voltage values are with respect to network ground terminal.
(2) An SN54S241J operating at free-air temperature above 116°C requires a heat sink that provides a thermal resistance from case to free air, $R_{\theta CA}$, of not more that 40°C/W.

6.4 Thermal Information

THERMAL METRIC(1)		SN74LS240, SN74LS244	SN74LS24x, SN74S24x		SN74LS24x	UNIT
		DB (SSOP)	DW (SOIC)	N (PDIP)	NS (SOP)	
		20 PINS	20 PINS	20 PINS	20 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance(2)(3)	94.3	90.3	50.6	76.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	55.9	45.5	37.4	42.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	49.5	48.1	31.5	44.1	°C/W
ψ_{JT}	Junction-to-top characterization parameter	21.3	19.4	24	19.2	°C/W
ψ_{JB}	Junction-to-board characterization parameter	49.1	47.6	31.4	43.7	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.
(2) Voltage values are with respect to network ground terminal.
(3) The package thermal impedance is calculated in accordance with JESD 51-7.

6.5 Electrical Characteristics – SNx4LS24x

over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS(1)			MIN	TYP(2)	MAX	UNIT
V_{IK}	V_{CC} = MIN, I_I = –18 mA					–1.5	V
Hysteresis ($V_{T+} - V_{T-}$)	V_{CC} = MIN			0.2	0.4		V
V_{OH}	V_{CC} = MIN, I_{OH} = –3 mA, V_{IH} = 2 V, V_{IL} = MAX			2.4	3.4		V
	V_{CC} = MIN, I_{OH} = MAX, V_{IH} = 2 V, V_{IL} = 0.5 V			2			
V_{OL}	V_{CC} = MIN, V_{IL} = MAX, V_{IH} = 2 V		I_{OL} = 12 mA, SN54LS24x			0.4	V
			I_{OL} = 24 mA, SN74LS24x			0.5	
I_{OZH}	V_{CC} = MAX, V_{IL} = MAX, V_{IH} = 2 V, V_O = 2.7 V					20	µA
I_{OZL}	V_{CC} = MAX, V_{IL} = MAX, V_{IH} = 2 V, V_O = 0.4 V					–20	µA
I_I	V_{CC} = MAX, V_I = 7 V					0.1	mA
I_{IH}	V_{CC} = MAX, V_I = 2.7 V					20	µA
I_{IL}	V_{CC} = MAX, V_{IL} = 0.4 V					–0.2	mA
I_{OS}(3)	V_{CC} = MAX			–40		–225	mA
I_{CC}	V_{CC} = MAX, output open	Outputs high	All		17	27	mA
		Outputs low	SNx4LS240		26	44	
			SNx4LS241, SNx4LS244		27	46	
		Outputs disabled	SNx4LS240		29	50	
			SNx4LS241, SNx4LS244		32	54	

(1) For conditions shown as minimum or maximum, use the appropriate value specified under recommended operating conditions.
(2) All typical values are at V_{CC} = 5 V and T_A = 25°C.
(3) Not more than one output must be shorted at a time, and duration of the short-circuit must not exceed one second.

6.6 Electrical Characteristics – SNx4S24x

over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS(1)	MIN	TYP(2)	MAX	UNIT
V_{IK}	V_{CC} = MIN, I_I = –18 mA			–1.2	V
Hysteresis ($V_{T+} - V_{T-}$)	V_{CC} = MIN	0.2	0.4		V
V_{OH}	V_{CC} = MIN, I_{OH} = –1 mA, V_{IH} = 2 V, V_{IL} = 0.8 V, SN74S24x only	2.7			V
	V_{CC} = MIN, I_{OH} = –3 mA, V_{IH} = 2 V, V_{IL} = 0.8 V	2.4	3.4		
	V_{CC} = MIN, I_{OH} = MAX, V_{IH} = 2 V, V_{IL} = 0.5 V	2			
V_{OL}	V_{CC} = MIN, V_{IL} = MAX, V_{IH} = 2 V, I_{OL} = 0.8 V			0.55	V

(1) For conditions shown as minimum or maximum, use the appropriate value specified under recommended operating conditions.
(2) All typical values are at V_{CC} = 5 V, T_A = 25°C.

Electrical Characteristics – SNx4S24x (continued)

over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS[1]			MIN	TYP[2]	MAX	UNIT
I_{OZH}	V_{CC} = MAX, V_{IL} = 0.8 V, V_{IH} = 2 V, V_O = 2.4 V					50	µA
I_{OZL}	V_{CC} = MAX, V_{IL} = MAX, V_{IH} = 2 V, V_O = 0.5 V					–50	µA
I_I	V_{CC} = MAX, V_I = 5.5 V					1	mA
I_{IH}	V_{CC} = MAX, V_I = 2.7 V					50	µA
I_{IL}	V_{CC} = MAX, V_{IL} = 0.5 V		Any A			–400	µA
			Any G			–2	mA
I_{OS}[3]	V_{CC} = MAX			–50		–225	mA
I_{CC}	V_{CC} = MAX, output open	Outputs high	SN54S240		80	123	mA
			SN74S240		80	135	
			SN54S241, SN54S244		95	147	
			SN74S241, SN74S244		95	160	
		Outputs low	SN54S240		100	145	
			SN74S240		100	150	
			SN54S241, SN54S244		120	170	
			SN74S241, SN74S244		120	180	
		Outputs disabled	SN54S240		100	145	
			SN74S240		100	150	
			SN54S241, SN54S244		120	170	
			SN74S241, SN74S244		120	180	

(3) Not more than one output must be shorted at a time, and duration of the short-circuit must not exceed one second.

6.7 Switching Characteristics – SNx4LS24x

V_{CC} = 5 V, T_A = 25°C (see *SN54LS24x and SN74LS24x Devices*)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	R_L = 667 Ω, C_L = 45 pF	SNx4LS240		9	14	ns
		SNx4LS241, SNx4LS244		12	18	
t_{PHL}	R_L = 667 Ω, C_L = 45 pF			12	18	ns
t_{PZL}	R_L = 667 Ω, C_L = 45 pF			20	30	ns
t_{PZH}	R_L = 667 Ω, C_L = 45 pF			15	23	ns
t_{PLZ}	R_L = 667 Ω, C_L = 5 pF			10	20	ns
t_{PHZ}	R_L = 667 Ω, C_L = 5 pF			15	25	ns

6.8 Switching Characteristics – SNx4S24x

V_{CC} = 5 V and T_A = 25°C (see *SN54S24x and SN74S24x Devices*)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	R_L = 90 Ω, C_L = 50 pF	SNx4S240		4.5	7	ns
		SNx4S241, SNx4S244		6	9	
t_{PHL}	R_L = 90 Ω, C_L = 50 pF	SNx4S240		4.5	7	ns
		SNx4S241, SNx4S244		6	9	
t_{PZL}	R_L = 90 Ω, C_L = 50 pF			10	15	ns
t_{PZH}	R_L = 90 Ω, C_L = 50 pF	SNx4S240		6.5	10	ns
		SNx4S241, SNx4S244		8	12	
t_{PLZ}	R_L = 90 Ω, C_L = 5 pF			10	15	ns
t_{PHZ}	R_L = 90 Ω, C_L = 5 pF			6	9	ns

6.9 Typical Characteristics

V_{CC} = 5 V, T_A = 25°C, C_L = 45 pF, and R_L = 667 Ω (unless otherwise noted)

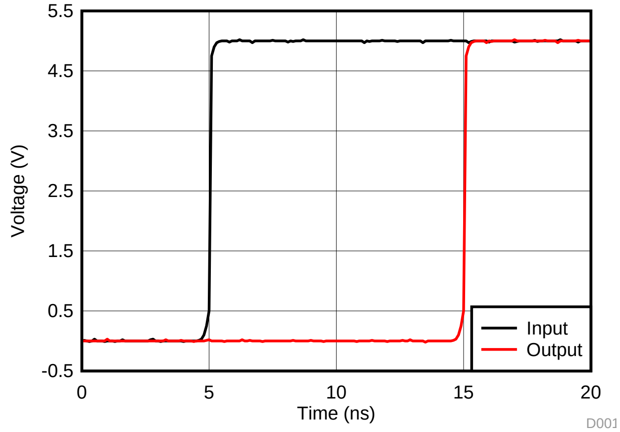


Figure 1. Simulated Propagation Delay From Input to Output

7 Parameter Measurement Information

7.1 SN54LS24x and SN74LS24x Devices

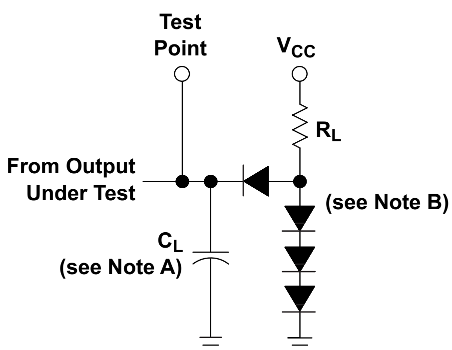


Figure 2. Load Circuit, For 2-State Totem-Pole Outputs

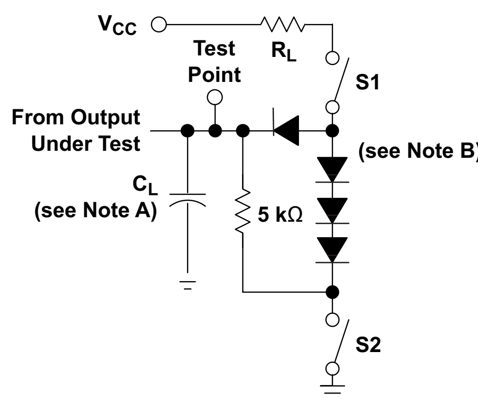


Figure 4. Load Circuit, For 3-State Outputs

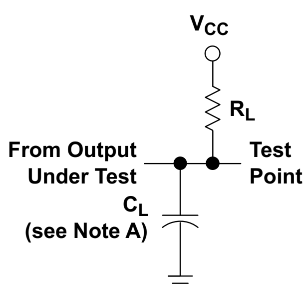


Figure 3. Load Circuit, For Open-Collector Outputs

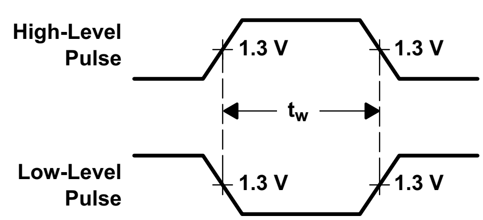


Figure 5. Voltage Waveforms, Pulse Durations

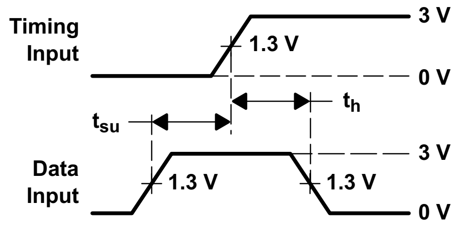


Figure 6. Voltage Waveforms, Setup and Hold Times

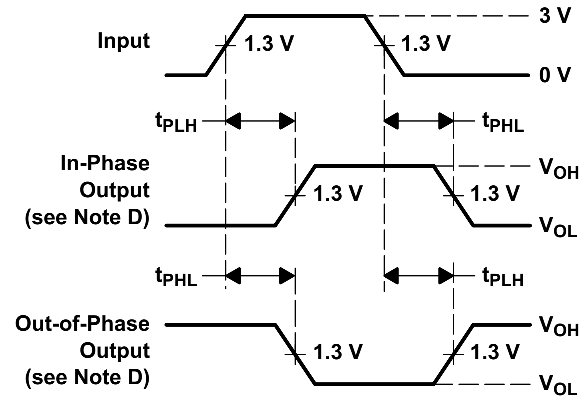
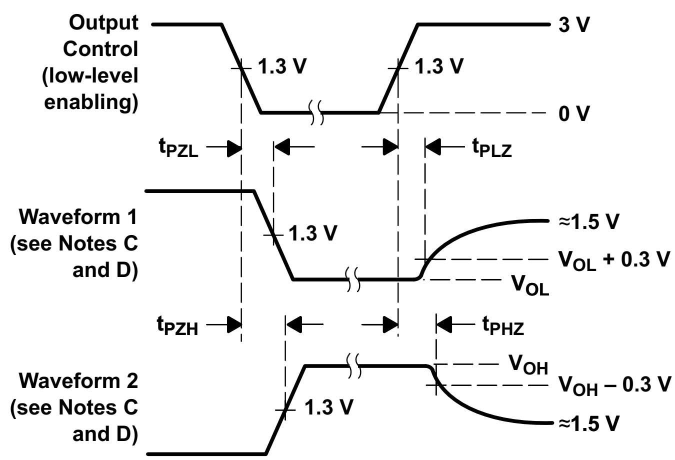


Figure 7. Voltage Waveforms, Propagation Delay Times



A. C_L includes probe and jig capacitance.

B. All diodes are 1N3064 or equivalent.

C. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.

D. S1 and S2 are closed for t_{PLH}, t_{PHL}, t_{PHZ}, and t_{PLZ}; S1 is open and S2 is closed for t_{PZH}; S1 is closed and S2 is open for t_{PZL}.

E. Phase relationships between inputs and outputs have been chosen arbitrarily for these examples.

F. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O is approximately 50 Ω, t_r ≤ 15 ns, t_f ≤ 6 ns.

G. The outputs are measured one at a time with one input transition per measurement.

Figure 8. Voltage Waveforms, Enable and Disable Times, 3-State Outputs

7.2 SN54S24x and SN74S24x Devices

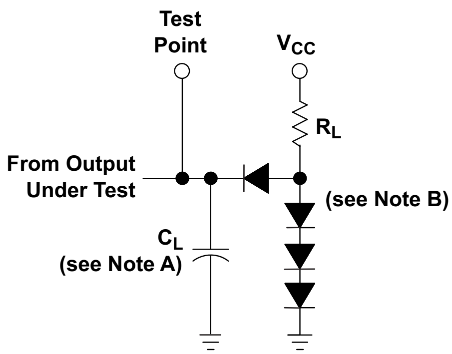


Figure 9. Load Circuit, For 2-State Totem-Pole Outputs

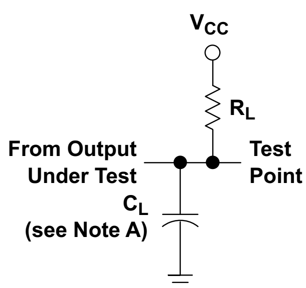


Figure 10. Load Circuit, For Open-Collector Outputs

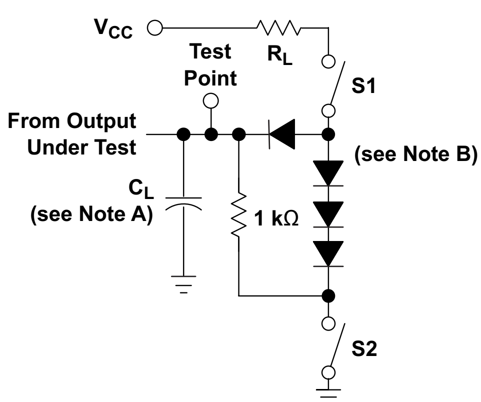


Figure 11. Load Circuit, For 3-State Outputs

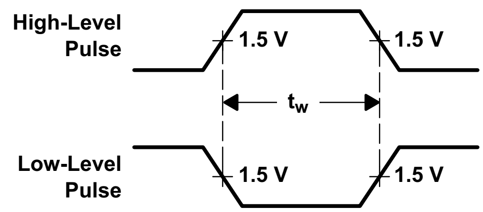


Figure 12. Voltage Waveforms, Pulse Durations

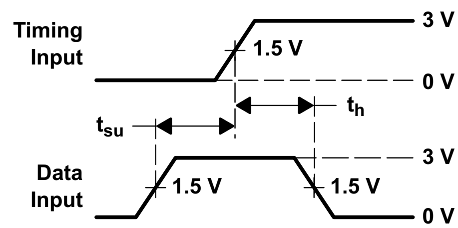


Figure 13. Voltage Waveforms, Setup and Hold Times

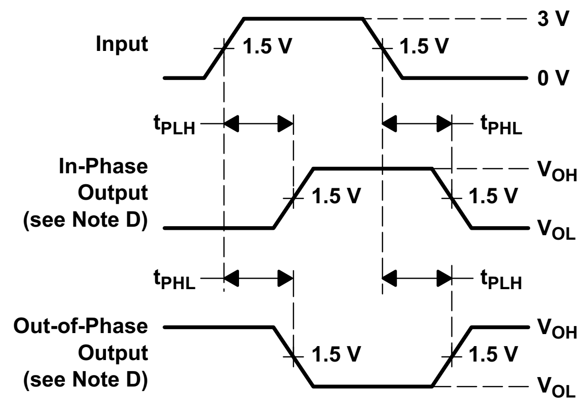
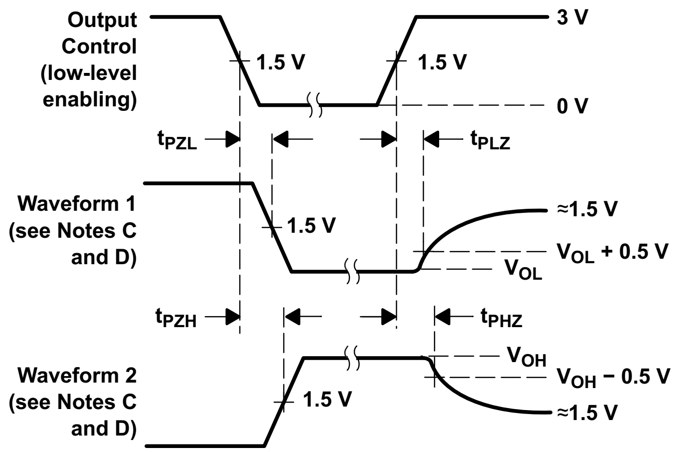


Figure 14. Voltage Waveforms, Propagation Delay Times



A. C_L includes probe and jig capacitance.

B. All diodes are 1N3064 or equivalent.

C. Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high except when disabled by the output control.

D. S1 and S2 are closed for t_{PLH}, t_{PHL}, t_{PHZ}, and t_{PLZ}; S1 is open and S2 is closed for t_{PZH}; S1 is closed and S2 is open for t_{PZL}.

E. All input pulses are supplied by generators having the following characteristics: PRR ≤ 1 MHz, Z_O is approximately 50 Ω; t_r and t_f ≤ 7 ns for SN54LS24x and SN74LS24x devices, and t_r and t_f ≤ 2.5 ns for SN54S24x and SN74S24x devices.

F. The outputs are measured one at a time with one input transition per measurement.

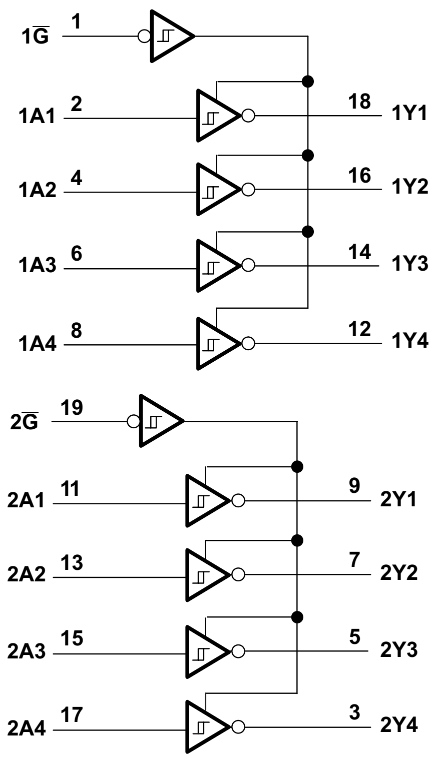
Figure 15. Voltage Waveforms, Enable and Disable Times, 3-State Outputs

8 Detailed Description

8.1 Overview

This device is organized as two 4-bit buffers and drivers with separate output-enable ($\overline{G}$) inputs. When $\overline{G}$ is low, the device passes data from the A inputs to the Y outputs. When $\overline{G}$ is high, the outputs are in the high impedance state. Inputs can be driven from either 3.3-V or 5-V devices. This feature allows the use of this device as a translator in a mixed 3.3-V and 5-V system environment. To ensure the high-impedance state during power up or power down, $\overline{G}$ must be tied to V_{CC} through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

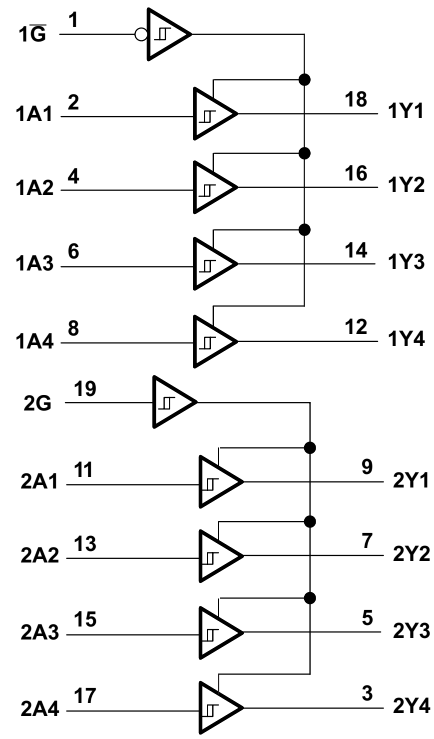
8.2 Functional Block Diagrams



Copyright © 2016, Texas Instruments Incorporated

Pin numbers shown are for DB, DW, J, N, NS, and W packages

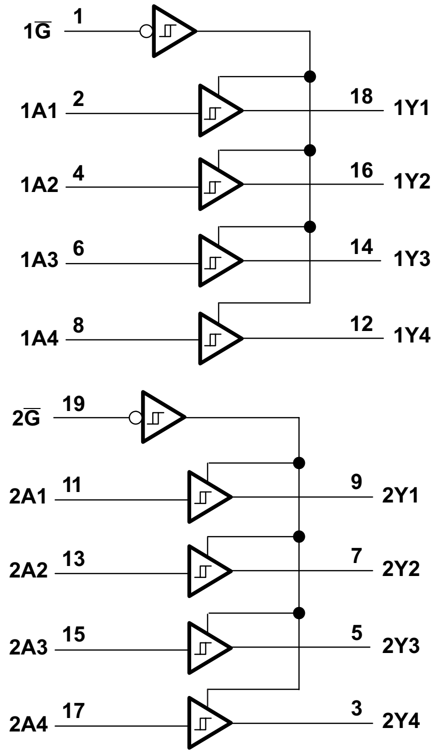
Figure 16. SNx4LS240 and SNx4S240 Logic Diagram



Copyright © 2016, Texas Instruments Incorporated

Pin numbers shown are for DB, DW, J, N, NS, and W packages

Figure 17. SNx4LS241 and SNx4S241 Logic Diagram



Copyright © 2016, Texas Instruments Incorporated

Pin numbers shown are for DB, DW, J, N, NS, and W packages

Figure 18. SNx4LS244 and SNx4S244 Logic Diagram

8.3 Feature Description

8.3.1 3-State Outputs

The 3-state outputs can drive bus lines directly. All outputs can be put into high impedance mode through the $\overline{G}$ pin.

8.3.2 PNP Inputs

This device has PNP inputs which reduce dc loading on bus lines.

8.3.3 Hysteresis on Bus Inputs

The bus inputs have built-in hysteresis that improves noise margins.

8.4 Device Functional Modes

The SNx4LS24x and SNx4S24x devices can be used as inverting and non-inverting bus buffers for data line transmission and can isolate input to output by setting the $\overline{G}$ pin HIGH. Table 1, Table 2, and Table 3 list the function tables for all devices.

Table 1. SNx4LS240 and SNx4S240 Function Table

INPUTS		OUTPUTS
$\overline{G}$	A	Y
L	L	H
L	H	L
H	X	Z

Table 2. SNx4LS241 and SNx4S241 Function Table

CHANNEL 1			CHANNEL 2		
INPUTS		OUTPUT	INPUTS		OUTPUT
$1\overline{G}$	1A	1Y	2G	2A	2Y
L	L	L	H	L	L
L	H	H	H	H	H
H	X	Z	L	X	Z

Table 3. SNx4LS244 and SNx4S244 Function Table

INPUTS		OUTPUTS
$\overline{G}$	A	Y
L	L	L
L	H	H
H	X	Z

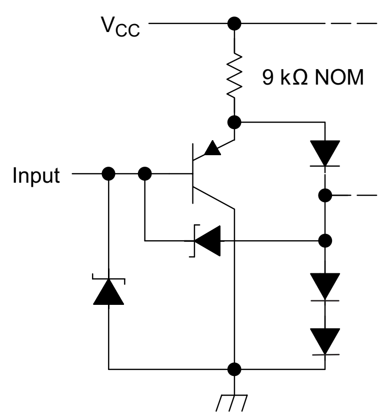
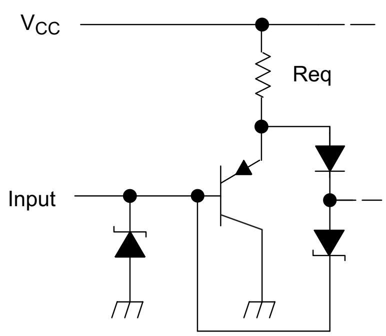


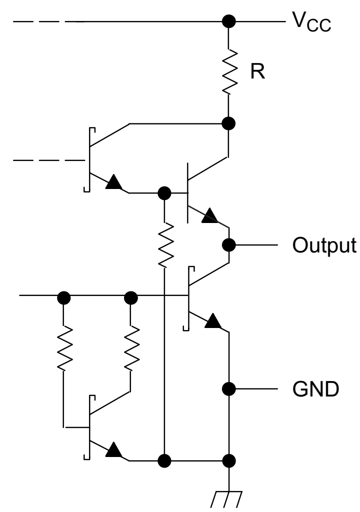
Figure 19. SNx4LS240, SNx4LS241, SNx4LS244 Equivalent of Each Input



G and $\overline{G}$ inputs: R_{eq} = 2 kΩ NOM

A inputs: R_{eq} = 2.8 kΩ NOM

Figure 20. SNx4S240, SNx4S241, SNx4S244 Equivalent of Each Input



SNx4LS240, SNx4LS241, SNx4LS244:
R = 50 Ω NOM

SNx4S240, SNx4S241, SNx4S244:
R = 25 Ω NOM

Figure 21. Typical of All Outputs

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

The SNx4LS24x, SNx4S24x octal buffers and line drivers are designed to be used for a multitude of bus interface type applications where output drive or PCB trace length is a concern.

9.2 Typical Application

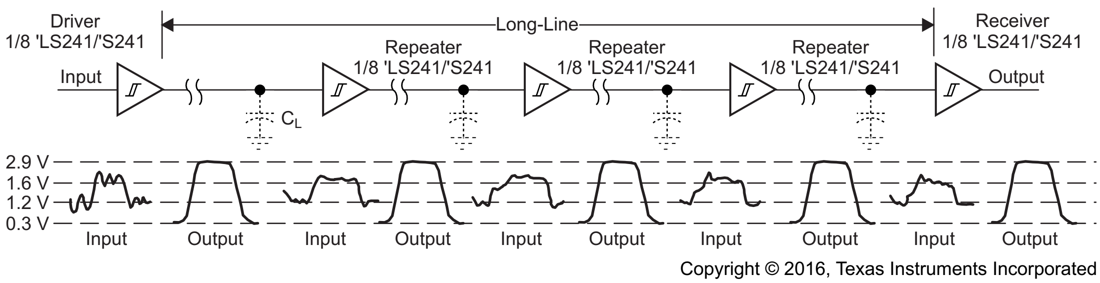


Figure 22. SNx4LS241 and SNx4S241 Used as Repeater or Level Restorer

9.2.1 Design Requirements

This device uses Schottky transistor logic technology. Take care to avoid bus contention because it can drive currents that would exceed maximum limits. The high drive creates fast edges into light loads, so routing and load conditions must be considered to prevent ringing.

9.2.2 Detailed Design Procedure

- Power Supply
  - Each device must maintain a supply voltage between 4.5 V and 5.5 V.
- Inputs
  - Input signals must meet the V_{IH} and V_{IL} specifications in *Electrical Characteristics – SNx4LS24x*.
  - Inputs leakage values (I_I, I_{IH}, I_{IL}) from *Electrical Characteristics – SNx4LS24x* must be considered.
- Outputs
  - Output signals are specified to meet the V_{OH} and V_{OL} specifications in *Electrical Characteristics – SNx4LS24x* as a minimum (the values could be closer to V_{CC} for high signals or GND for low signals).
  - TI recommends maintaining output currents as specified in *Recommended Operating Conditions*.
  - The part can be damaged by sourcing or sinking too much current (see *Electrical Characteristics – SNx4LS24x* for details).

Typical Application (continued)

9.2.3 Application Curve

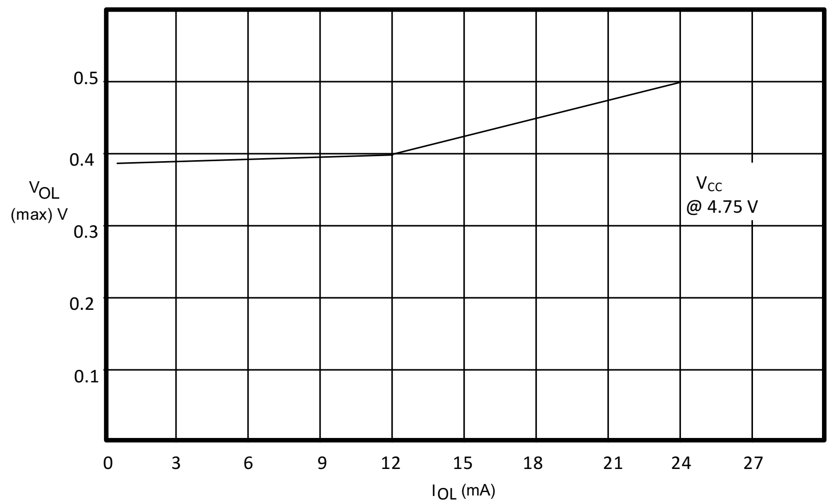
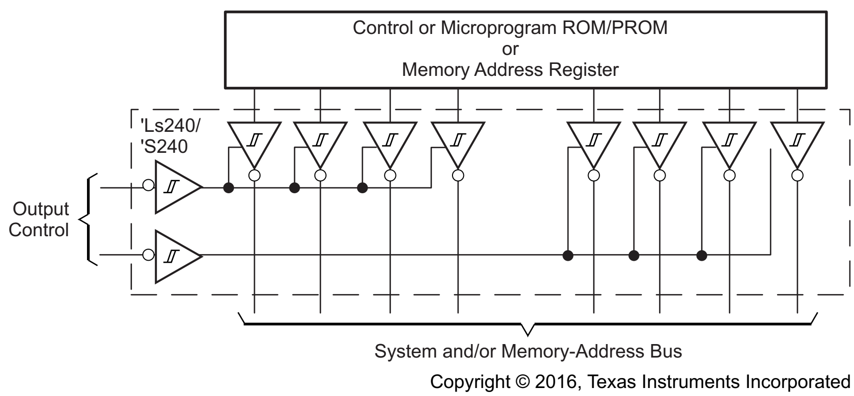


Figure 23. V_{OL} vs I_{OL}

9.3 System Examples

The SNx4LS240 and SNx4S240 devices can be used to buffer signals along a memory bus. The increased output drive helps data transmission reliability. Figure 24 shows a schematic of this example.



4-bit organization can be applied to handle binary or BCD

Figure 24. SNx4LS240 and SNx4S240 Used as System or Memory Bus Driver

The SNx4LS240 and SNx4S240 devices have two independently controlled 4-bit drivers, and can be used to buffer signals in a bidirectional manner along a data bus. Figure 25 shows the SNx4LS240 or SNx4S240 used in this manner.

System Examples (continued)

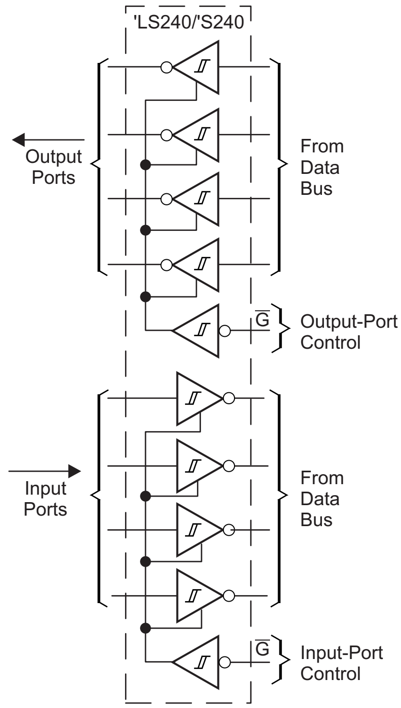


Figure 25. Independent 4-Bit But Drivers/Receivers in a Single Package

The enable pins on the SNx4LS241 and SNx4S241 devices can be used to help direct signals along a shared party-line bus. Figure 26 shows a general configuration of how to implement this structure. Take care to ensure that bus contention does not occur.

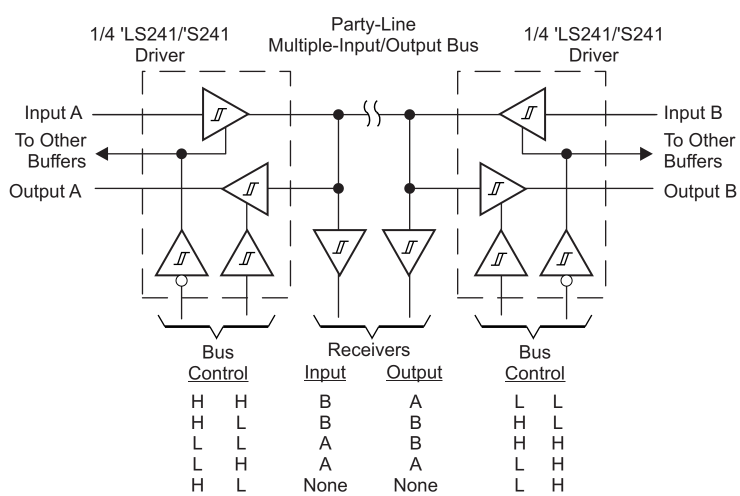


Figure 26. Party-Line Bus System With Multiple Inputs, Outputs, and Receivers

10 Power Supply Recommendations

The power supply can be any voltage between the minimum and maximum supply voltage rating located in *Recommended Operating Conditions*. Each V_{CC} pin must have a good bypass capacitor to prevent power disturbance. For devices with a single supply, TI recommends a 0.1-µF bypass capacitor. If there are multiple V_{CC} pins, TI recommends a 0.01-µF or 0.022-µF bypass capacitors for each power pin. It is acceptable to parallel multiple bypass capacitors to reject different frequencies of noise. Two bypass capacitors of value 0.1 µF and 1 µF are commonly used in parallel. For best results, install the bypass capacitor(s) as close to the power pin as possible.

11 Layout

11.1 Layout Guidelines

When using multiple bit logic devices, inputs must not be left floating. In many applications, some channels of the SNx4LS24x, SNx4S24x are unused, and thus must be terminated properly. Because each transceiver channel pin can be either an input or an output, they must be treated as both when being terminated. Ground or V_{CC} (whichever is more convenient) can be used to terminate unused inputs; however, each unused channel should be terminated to the same logic level on both the A and Y side. For example, in Figure 27 unused channels are terminated correctly with both sides connected to the same voltage, while channel 8 is terminated incorrectly with each side being tied to a different voltage. The $\overline{G}$ input is also unused in this example, and is terminated directly to ground to permanently enable all outputs.

11.2 Layout Example

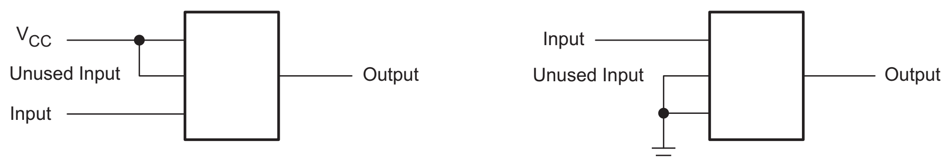


Figure 27. Example Demonstrating How to Terminate Unused Inputs and Channels of a Transceiver

12 Device and Documentation Support

12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 4. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	SUPPORT & COMMUNITY
SN54LS240	Click here	Click here	Click here	Click here
SN74LS241	Click here	Click here	Click here	Click here
SN74LS244	Click here	Click here	Click here	Click here
SN54S240	Click here	Click here	Click here	Click here
SN54S241	Click here	Click here	Click here	Click here
SN54S244	Click here	Click here	Click here	Click here
SN74LS240	Click here	Click here	Click here	Click here
SN74LS241	Click here	Click here	Click here	Click here
SN74LS244	Click here	Click here	Click here	Click here
SN74S240	Click here	Click here	Click here	Click here
SN74S241	Click here	Click here	Click here	Click here
SN74S241	Click here	Click here	Click here	Click here

12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.3 Community Resource

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-7801201VSA	ACTIVE	CFP	W	20	25	TBD	A42	N / A for Pkg Type	-55 to 125	5962-7801201VS A SNV54LS240W	Samples
7705701RA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7705701RA SNJ54LS244J	Samples
7705701SA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7705701SA SNJ54LS244W	Samples
78012012A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	78012012A SNJ54LS 240FK	Samples
7801201RA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7801201RA SNJ54LS240J	Samples
7801201SA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7801201SA SNJ54LS240W	Samples
JM38510/32401B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32401B2A	Samples
JM38510/32401BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32401BRA	Samples
JM38510/32401BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32401BSA	Samples
JM38510/32402B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32402B2A	Samples
JM38510/32402BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32402BRA	Samples
JM38510/32402BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32402BSA	Samples
JM38510/32403B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32403B2A	Samples
JM38510/32403BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403BRA	Samples
JM38510/32403BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403BSA	Samples
JM38510/32403SRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403SRA	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
JM38510/32403SSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403SSA	Samples
M38510/32401B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32401B2A	Samples
M38510/32401BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32401BRA	Samples
M38510/32401BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32401BSA	Samples
M38510/32402B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32402B2A	Samples
M38510/32402BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32402BRA	Samples
M38510/32402BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32402BSA	Samples
M38510/32403B2A	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	JM38510/ 32403B2A	Samples
M38510/32403BRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403BRA	Samples
M38510/32403BSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403BSA	Samples
M38510/32403SRA	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403SRA	Samples
M38510/32403SSA	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	JM38510/ 32403SSA	Samples
SN54LS240J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54LS240J	Samples
SN54LS241J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54LS241J	Samples
SN54LS244J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54LS244J	Samples
SN54S240J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54S240J	Samples
SN54S241J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54S241J	Samples
SN54S244J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SN54S244J	Samples
SN74LS240DBR	ACTIVE	SSOP	DB	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM		LS240	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
SN74LS240DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS240	Samples
SN74LS240DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS240	Samples
SN74LS240DWR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS240	Samples
SN74LS240DWRE4	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS240	Samples
SN74LS240N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74LS240N	Samples
SN74LS240NE4	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74LS240N	Samples
SN74LS240NSR	ACTIVE	SO	NS	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	74LS240	Samples
SN74LS241DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS241	Samples
SN74LS241DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS241	Samples
SN74LS241DWR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS241	Samples
SN74LS241N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74LS241N	Samples
SN74LS241NSR	ACTIVE	SO	NS	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	74LS241	Samples
SN74LS244DBR	ACTIVE	SSOP	DB	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DBRG4	ACTIVE	SSOP	DB	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DWE4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DWR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
SN74LS244DWRE4	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244DWRG4	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	LS244	Samples
SN74LS244N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74LS244N	Samples
SN74LS244NE4	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74LS244N	Samples
SN74LS244NSR	ACTIVE	SO	NS	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	74LS244	Samples
SN74LS244NSRG4	ACTIVE	SO	NS	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	74LS244	Samples
SN74S240DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S240	Samples
SN74S240DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S240	Samples
SN74S240N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74S240N	Samples
SN74S240NE4	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74S240N	Samples
SN74S241DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S241	Samples
SN74S241N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74S241N	Samples
SN74S244DW	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S244	Samples
SN74S244DWG4	ACTIVE	SOIC	DW	20	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S244	Samples
SN74S244DWR	ACTIVE	SOIC	DW	20	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	0 to 70	S244	Samples
SN74S244N	ACTIVE	PDIP	N	20	20	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	0 to 70	SN74S244N	Samples
SNJ54LS240FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	78012012A SNJ54LS 240FK	Samples
SNJ54LS240J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7801201RA	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
										SNJ54LS240J	
SNJ54LS240W	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7801201SA SNJ54LS240W	Samples
SNJ54LS241FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	SNJ54LS 241FK	Samples
SNJ54LS241J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54LS241J	Samples
SNJ54LS241W	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54LS241W	Samples
SNJ54LS244FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	SNJ54LS 244FK	Samples
SNJ54LS244J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7705701RA SNJ54LS244J	Samples
SNJ54LS244W	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	7705701SA SNJ54LS244W	Samples
SNJ54S240FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	SNJ54S 240FK	Samples
SNJ54S240J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54S240J	Samples
SNJ54S240W	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54S240W	Samples
SNJ54S241FK	ACTIVE	LCCC	FK	20	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	SNJ54S 241FK	Samples
SNJ54S241J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54S241J	Samples
SNJ54S244J	ACTIVE	CDIP	J	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54S244J	Samples
SNJ54S244W	ACTIVE	CFP	W	20	1	TBD	A42	N / A for Pkg Type	-55 to 125	SNJ54S244W	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF SN54LS240, SN54LS240-SP, SN54LS241, SN54LS244, SN54LS244-SP, SN54S240, SN54S241, SN54S244, SN74LS240, SN74LS241, SN74LS244, SN74S240, SN74S241, SN74S244 :

- Catalog: SN74LS240, SN54LS240, SN74LS241, SN74LS244, SN54LS244, SN74S240, SN74S241, SN74S244

- Military: SN54LS240, SN54LS241, SN54LS244, SN54S240, SN54S241, SN54S244

- Space: SN54LS240-SP, SN54LS244-SP

NOTE: Qualified Version Definitions:

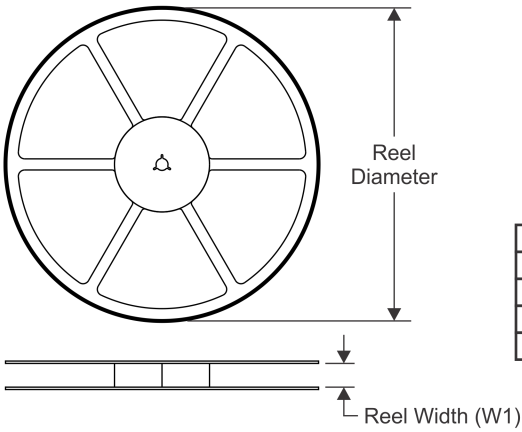
- Catalog - TI's standard catalog product

- Military - QML certified for Military and Defense Applications

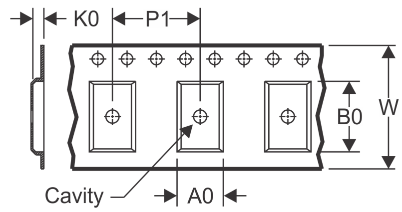
- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

TAPE AND REEL INFORMATION

REEL DIMENSIONS

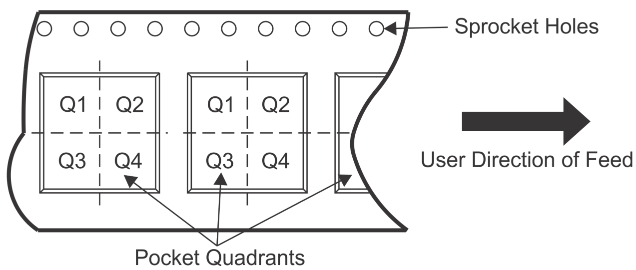


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

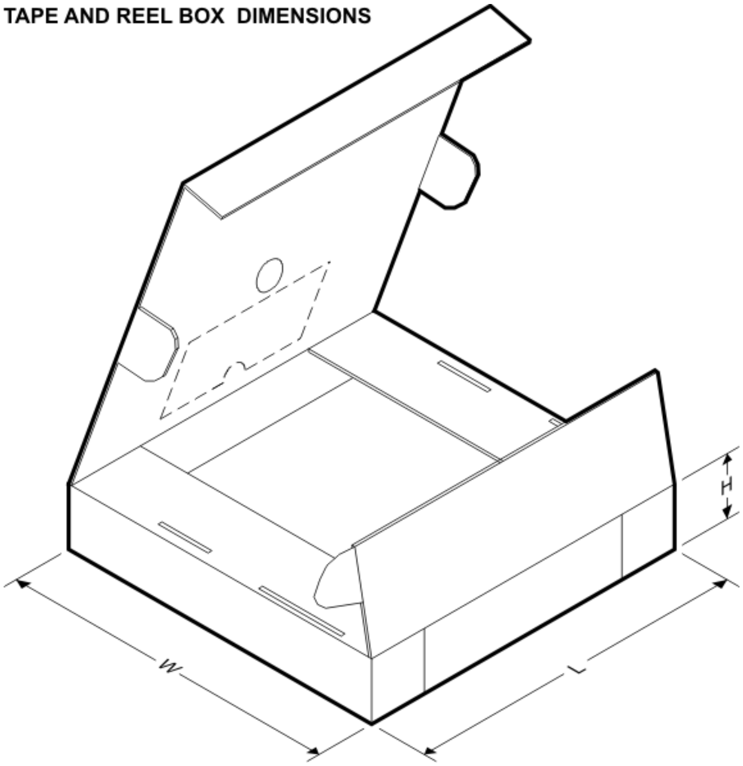
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
SN74LS240DBR	SSOP	DB	20	2000	330.0	16.4	8.2	7.5	2.5	12.0	16.0	Q1
SN74LS240DWR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
SN74LS240NSR	SO	NS	20	2000	330.0	24.4	8.4	13.0	2.5	12.0	24.0	Q1
SN74LS241DWR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
SN74LS241NSR	SO	NS	20	2000	330.0	24.4	8.4	13.0	2.5	12.0	24.0	Q1
SN74LS244DBR	SSOP	DB	20	2000	330.0	16.4	8.2	7.5	2.5	12.0	16.0	Q1
SN74LS244DWR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1
SN74LS244NSR	SO	NS	20	2000	330.0	24.4	8.4	13.0	2.5	12.0	24.0	Q1
SN74S244DWR	SOIC	DW	20	2000	330.0	24.4	10.8	13.3	2.7	12.0	24.0	Q1

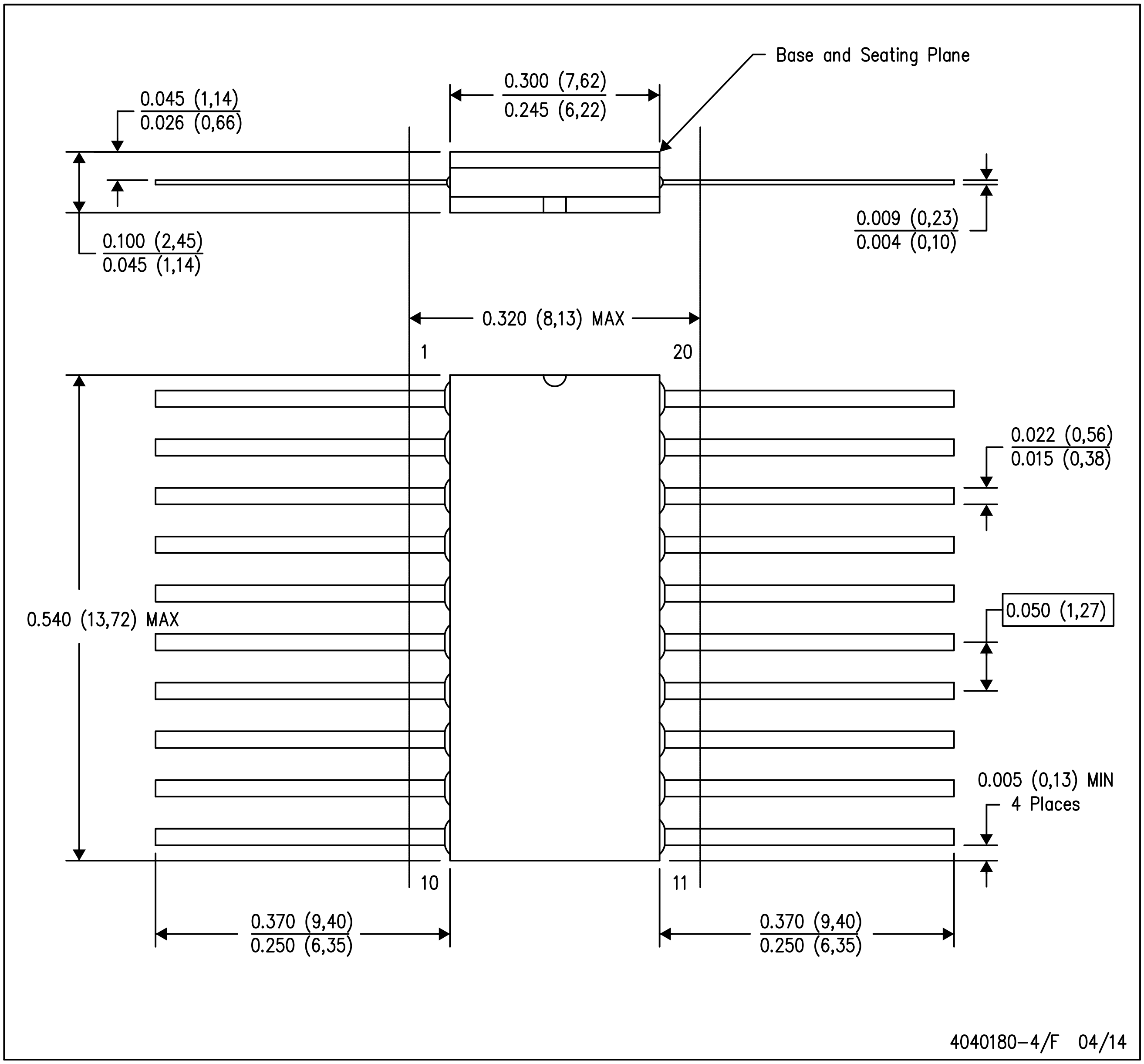
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
SN74LS240DBR	SSOP	DB	20	2000	367.0	367.0	38.0
SN74LS240DWR	SOIC	DW	20	2000	367.0	367.0	45.0
SN74LS240NSR	SO	NS	20	2000	367.0	367.0	45.0
SN74LS241DWR	SOIC	DW	20	2000	367.0	367.0	45.0
SN74LS241NSR	SO	NS	20	2000	367.0	367.0	45.0
SN74LS244DBR	SSOP	DB	20	2000	367.0	367.0	38.0
SN74LS244DWR	SOIC	DW	20	2000	367.0	367.0	45.0
SN74LS244NSR	SO	NS	20	2000	367.0	367.0	45.0
SN74S244DWR	SOIC	DW	20	2000	367.0	367.0	45.0

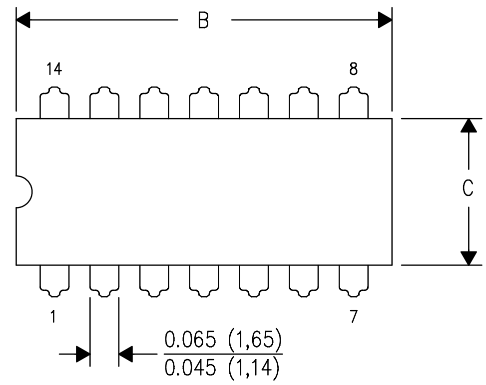
W (R–GDFP–F20) CERAMIC DUAL FLATPACK



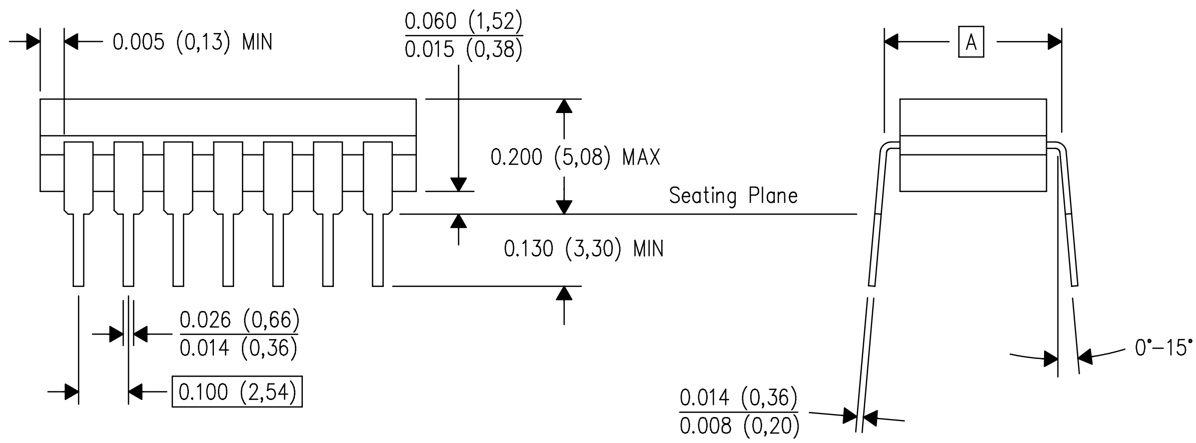
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification only.
- E. Falls within Mil–Std 1835 GDFP2–F20

J (R–GDIP–T**) CERAMIC DUAL IN–LINE PACKAGE

14 LEADS SHOWN



DIM \ PINS **	14	16	18	20
A	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC	0.300 (7,62) BSC
B MAX	0.785 (19,94)	.840 (21,34)	0.960 (24,38)	1.060 (26,92)
B MIN	——	——	——	——
C MAX	0.300 (7,62)	0.300 (7,62)	0.310 (7,87)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.220 (5,59)	0.245 (6,22)

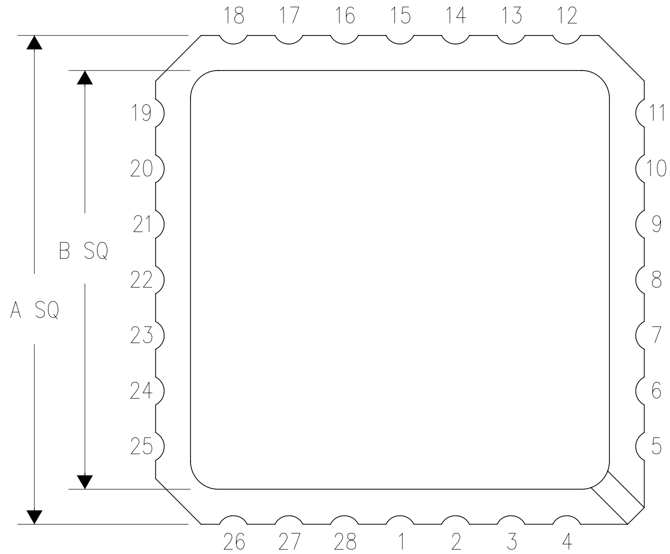


4040083/F 03/03

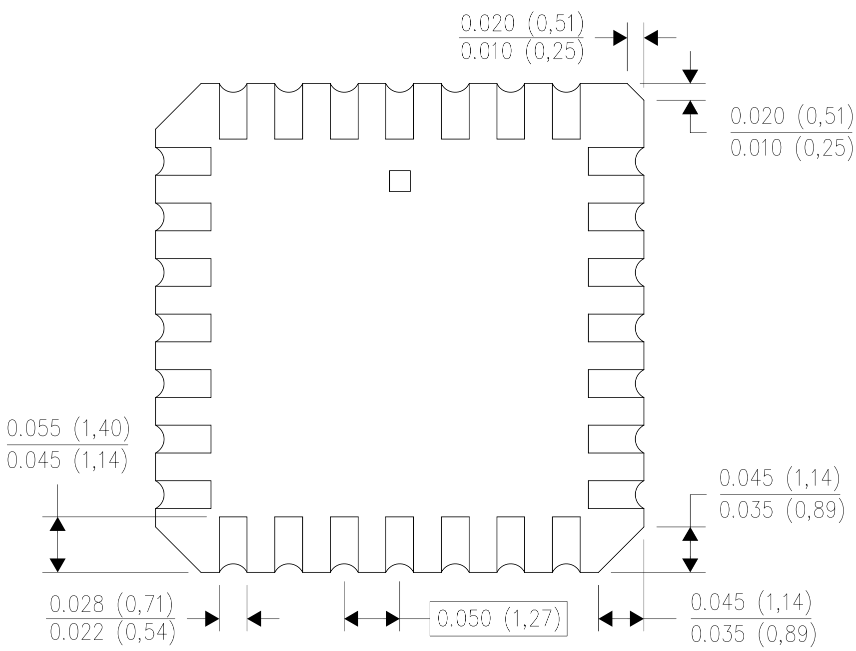
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package is hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification only on press ceramic glass frit seal only.
E. Falls within MIL STD 1835 GDIP1–T14, GDIP1–T16, GDIP1–T18 and GDIP1–T20.

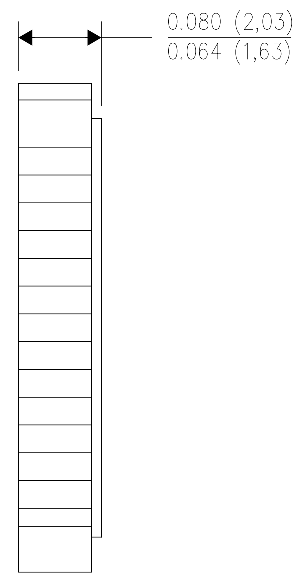
FK (S-CQCC-N**) LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



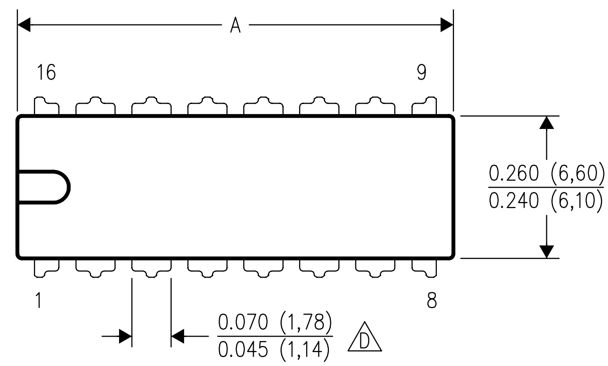


4040140/D 01/11

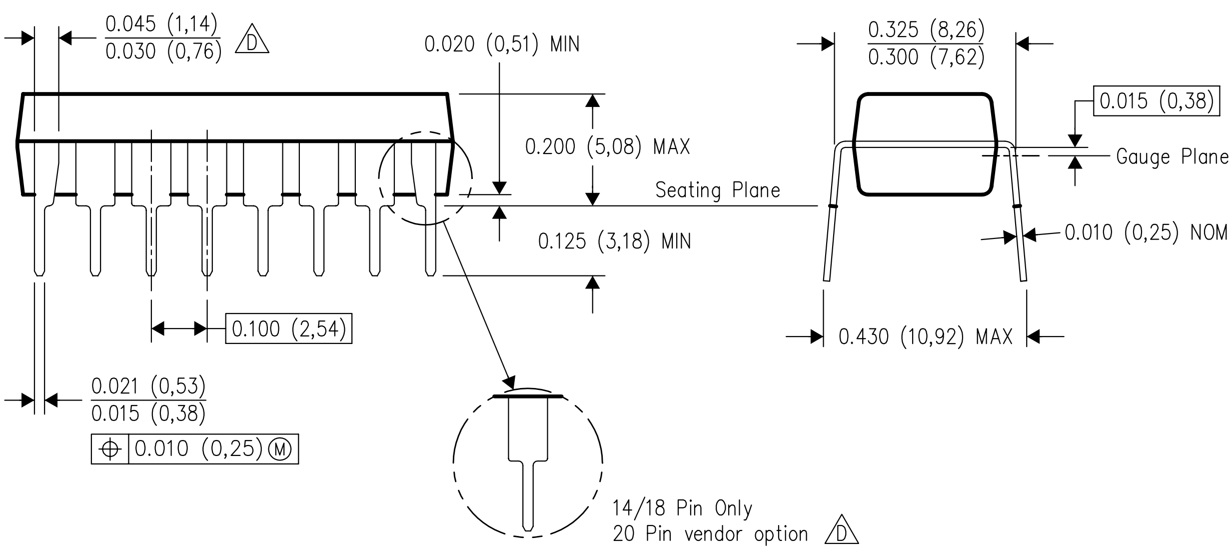
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a metal lid.
- D. Falls within JEDEC MS-004

N (R–PDIP–T**)   PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN

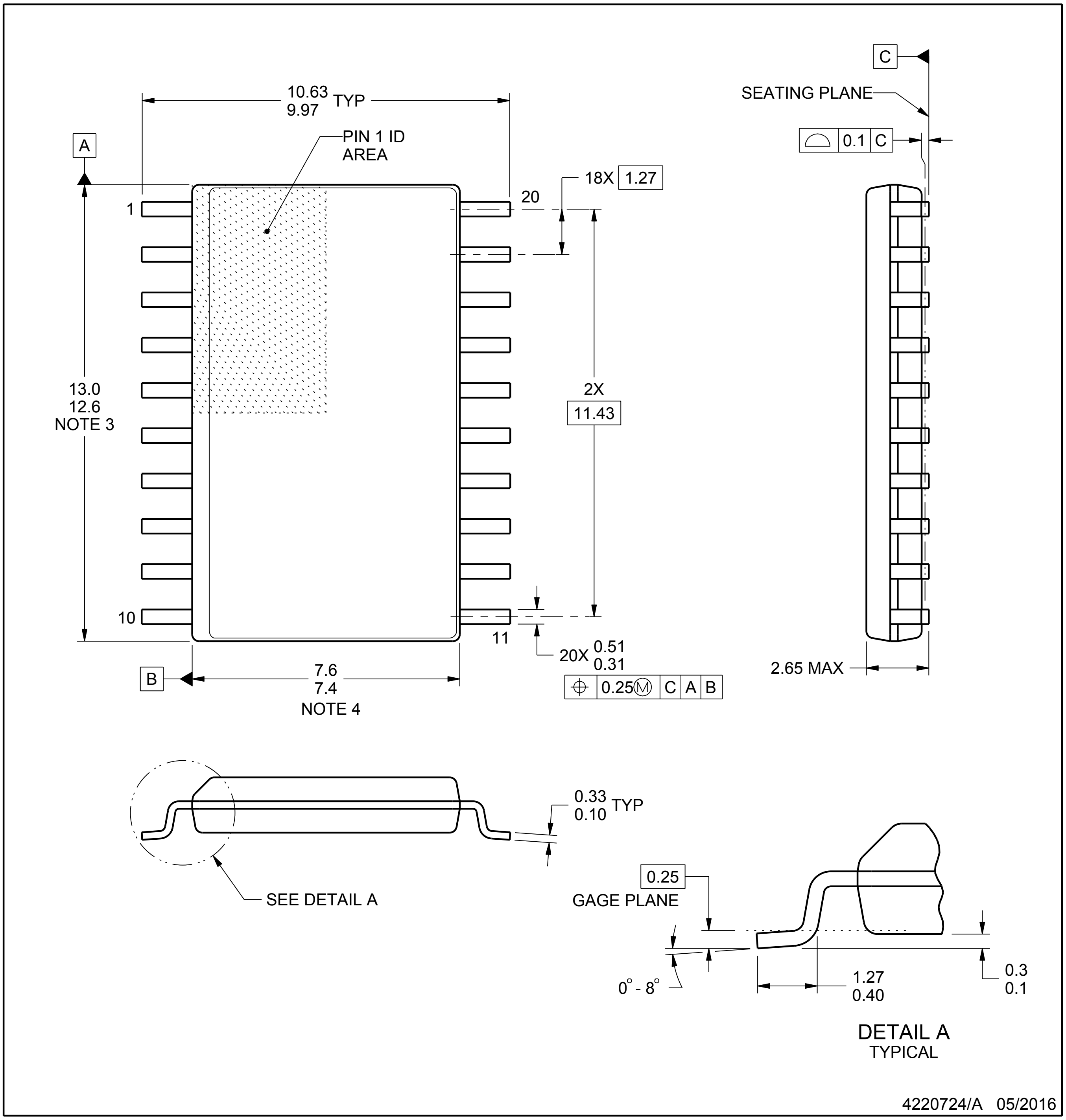


PINS ** / DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
(C) MS–001 VARIATION	AA	BB	AC	AD



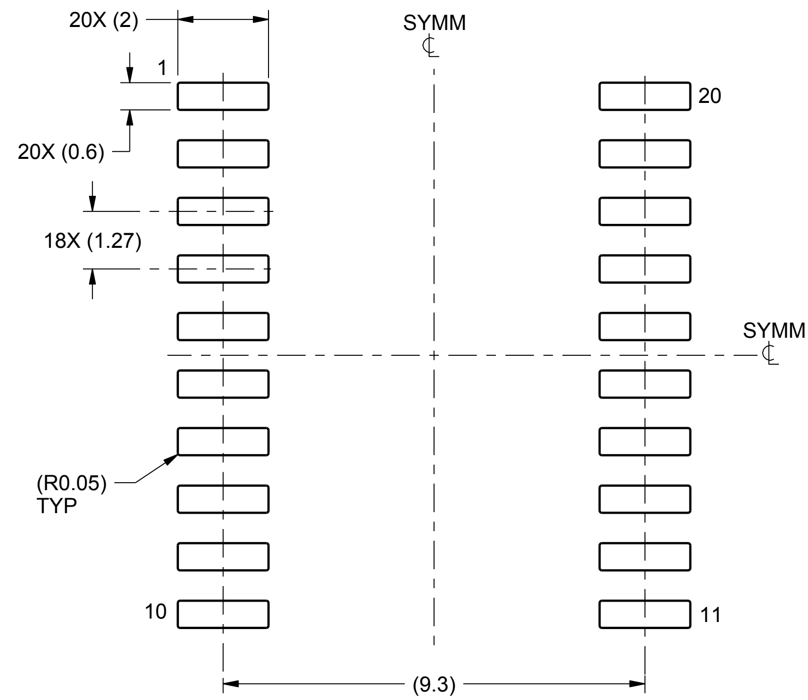
4040049/E 12/2002

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

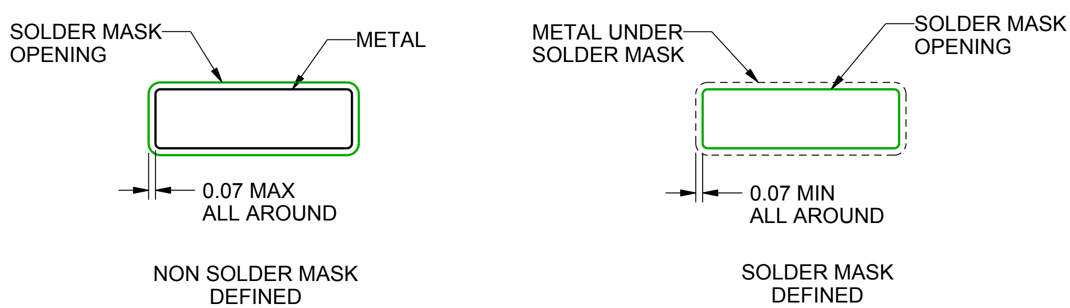


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm per side.
5. Reference JEDEC registration MS-013.



LAND PATTERN EXAMPLE
SCALE:6X

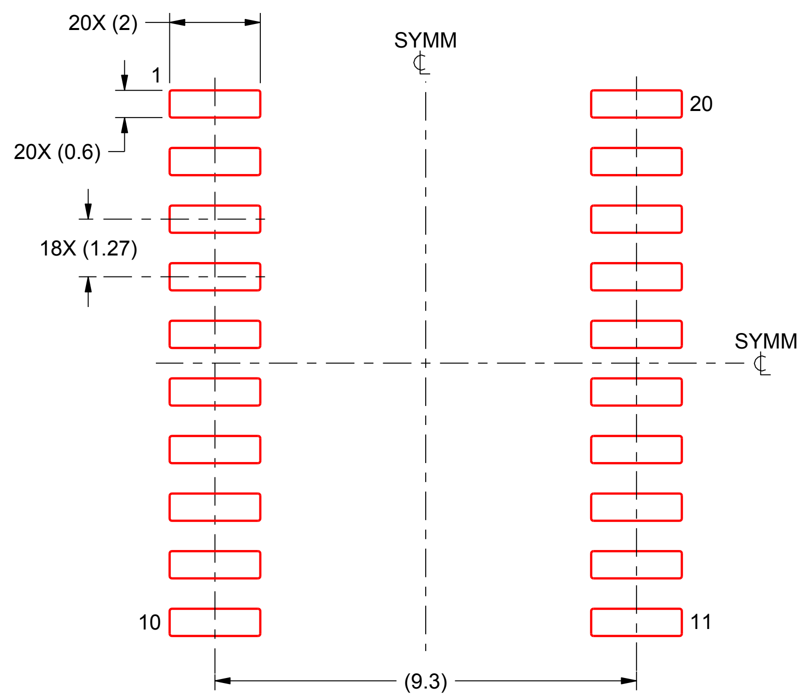


SOLDER MASK DETAILS

4220724/A 05/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:6X

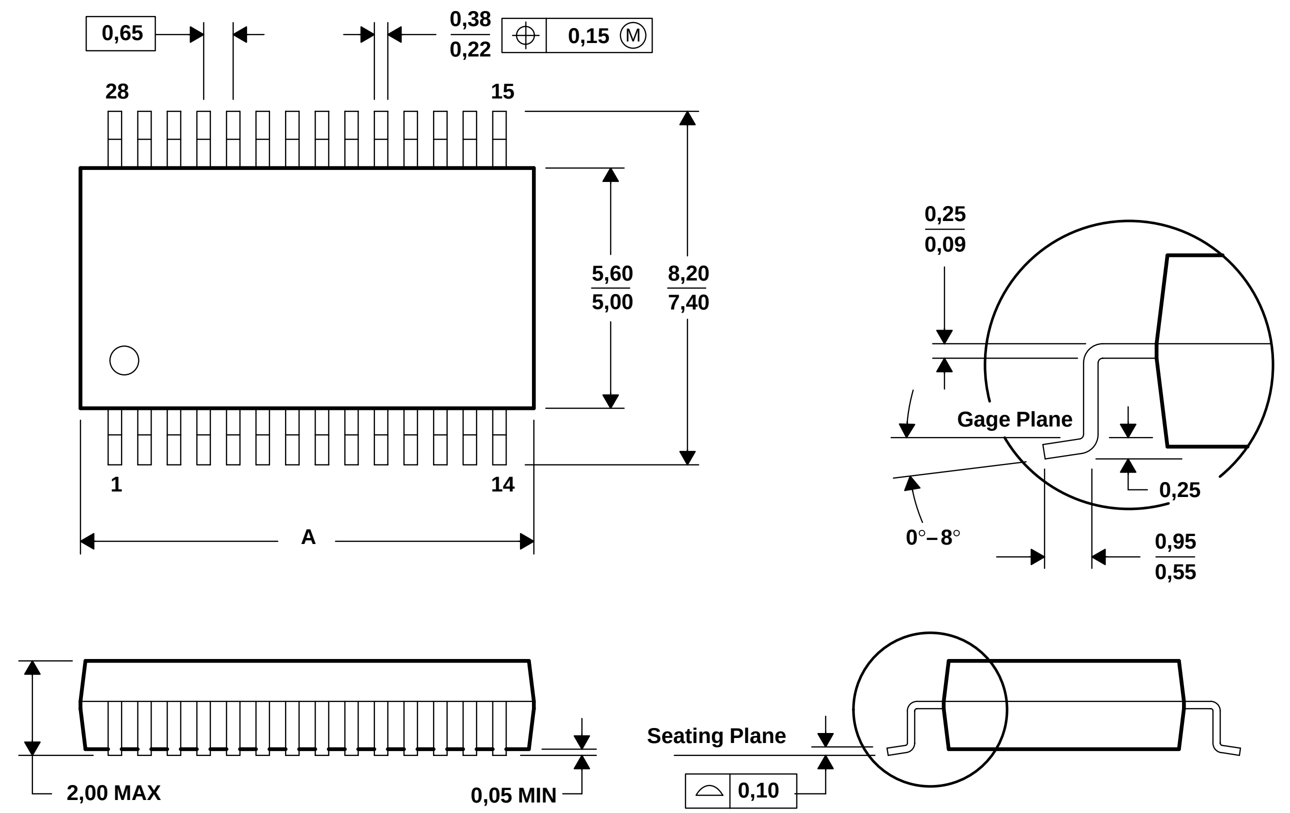
4220724/A 05/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

DB (R-PDSO-G)** **PLASTIC SMALL-OUTLINE**

28 PINS SHOWN



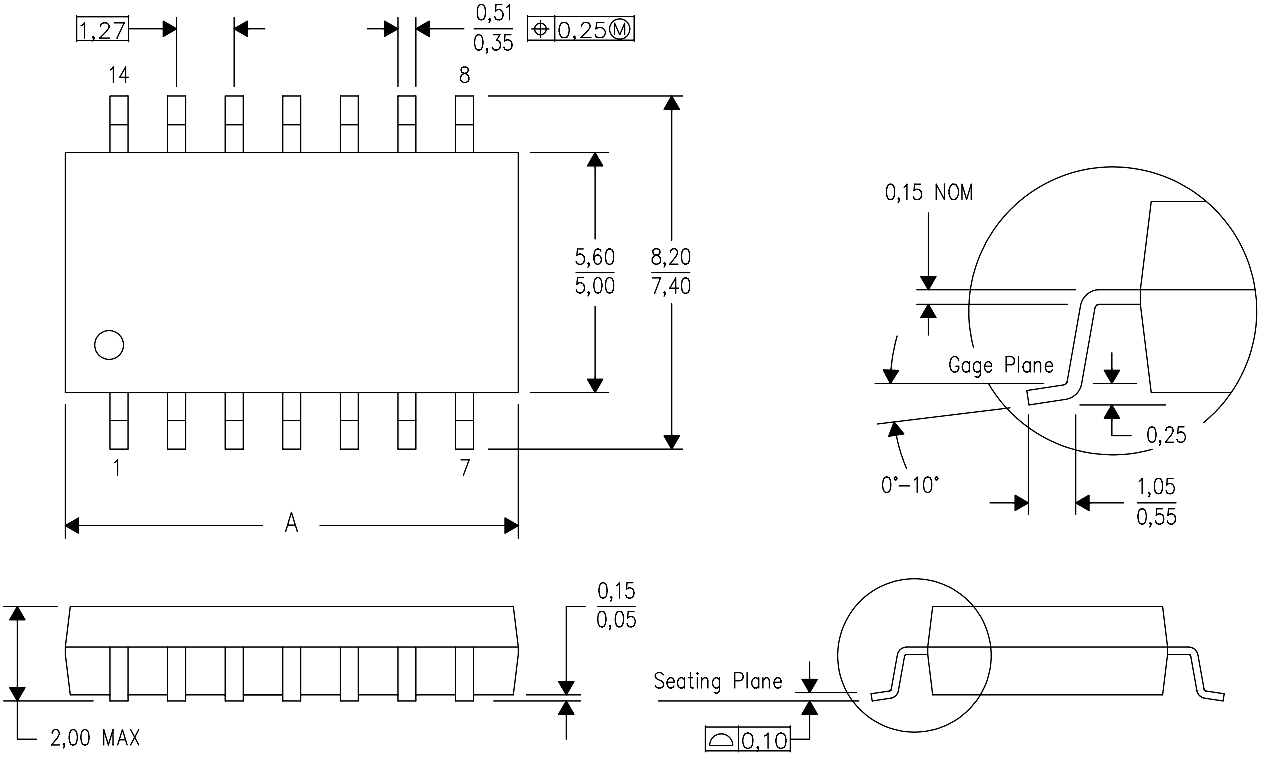
DIM \ PINS **	14	16	20	24	28	30	38
A MAX	6,50	6,50	7,50	8,50	10,50	10,50	12,90
A MIN	5,90	5,90	6,90	7,90	9,90	9,90	12,30

4040065 /E 12/01

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-150

NS (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14-PINS SHOWN



PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

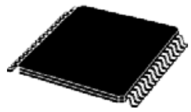
VNH5019A-E

Automotive fully integrated H-bridge motor driver

Features

Type	$R_{DS(on)}$	I_{out}	V_{ccmax}
VNH5019A-E	18 mΩ typ (per leg)	30 A	41 V

- ECOPACK®: lead free and RoHS compliant
- Automotive Grade: compliance with AEC guidelines
- Output current: 30 A
- 3 V CMOS compatible inputs
- Undervoltage and overvoltage shutdown
- High-side and low-side thermal shutdown
- Cross-conduction protection
- Current limitation
- Very low standby power consumption
- PWM operation up to 20 khz
- Protection against:
  - Loss of ground and loss of V_{CC}
- Current sense output proportional to motor current
- Charge pump output for reverse polarity protection
- Output protected against short to ground and short to V_{CC}



MultiPowerSO-30™

Description

The VHN5019A-E is a full bridge motor driver intended for a wide range of automotive applications. The device incorporates a dual monolithic high-side drivers and two low-side switches. The high-side driver switch is designed using STMicroelectronics' well known and proven proprietary VIPower® M0 technology that allows to efficiently integrate on the same die a true Power MOSFET with an intelligent signal/protection circuit.

The three dice are assembled in MultiPowerSO-30 package on electrically isolated lead-frames. This package, specifically designed for the harsh automotive environment offers improved thermal performance thanks to exposed die pads. The input signals IN_A and IN_B can directly interface to the microcontroller to select the motor direction and the brake condition.

The $DIAG_A/EN_A$ or $DIAG_B/EN_B$, when connected to an external pull-up resistor, enable one leg of the bridge. They also provide a feedback digital diagnostic signal. The CS pin allows to monitor the motor current by delivering a current proportional to its value when CS_DIS pin is driven low or left open. The PWM, up to 20 KHz, lets us to control the speed of the motor in all possible conditions. In all cases, a low-level state on the PWM pin turns-off both the LS_A and LS_B switches. When PWM rises to a high-level, LS_A or LS_B turn-on again depending on the input pin state.

Output current limitation and thermal shutdown protects the concerned high-side in short to ground condition.

The short to battery condition is revealed by the overload detector or by thermal shutdown that latches off the relevant low-side.

Active V_{CC} pin voltage clamp protects the device against low energy spikes in all configurations for the motor.

CP pin provides the necessary gate drive for an external n-channel PowerMOS used for reverse polarity protection.

Contents

List of tables

List of figures

1 Block diagram and pin description

Figure 1. Block diagram

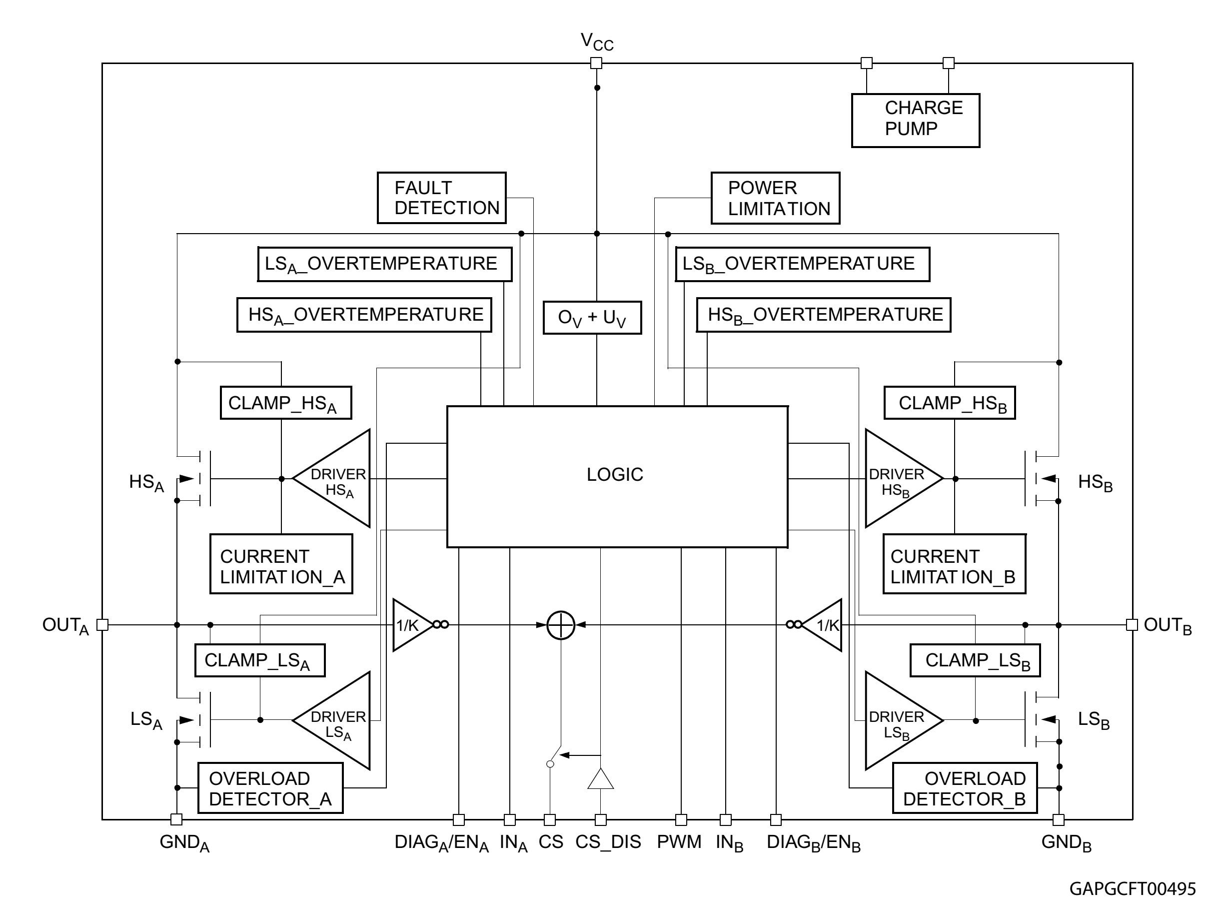


Figure 2. Configuration diagram (top view)

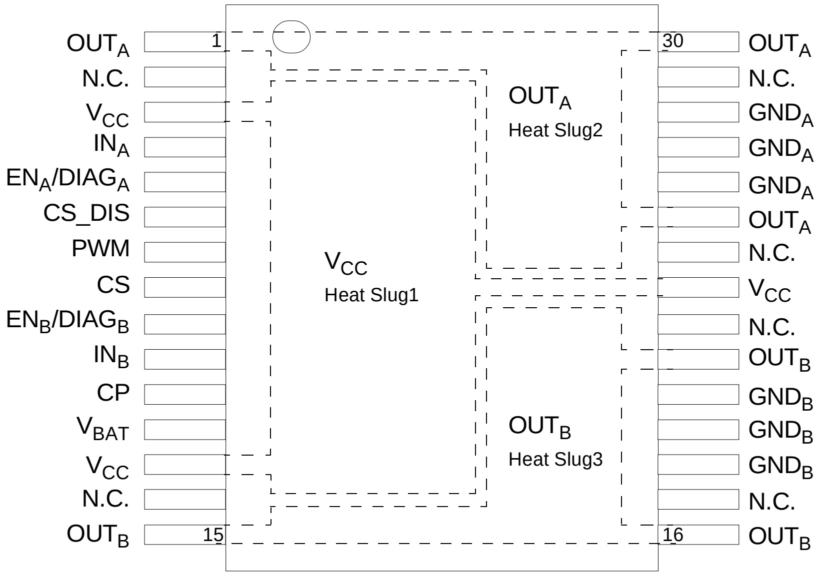


Table 1. Suggested connections for unused and not connected pins

Connection / pin	Current sense	N.C.	OUTx	INPUTx, PWM DIAGx/ENx CS_DIS
Floating	Not allowed	X	X	X
To ground	Through 1 kΩ resistor	X	Not allowed	Through 10 kΩ resistor

Table 2. Pin definitions and functions

Pin	Symbol	Function
1, 25, 30	OUT_A, Heat Slug2	Source of high-side switch A / drain of low-side switch A, power connection to the motor
2,14,17, 22, 24,29	N.C.	Not connected
3, 13, 23	V_{CC}, Heat Slug1	Drain of high-side switches and connection to the drain of the external PowerMOS used for the reverse battery protection
12	V_{BAT}	Battery connection and connection to the source of the external PowerMOS used for the reverse battery protection
5	$EN_A/DIAG_A$	Status of high-side and low-side switches A; open drain output. This pin must be connected to an external pull-up resistor. When externally pulled low, it disables half-bridge A. In case of fault detection (thermal shutdown of a high-side FET or excessive ON-state voltage drop across a low-side FET), this pin is pulled low by the device (see *Table 13: Truth table in fault conditions (detected on OUTA)*)

Table 2. Pin definitions and functions (continued)

Pin	Symbol	Function
6	CS_DIS	Active high CMOS compatible pin to disable the current sense pin
4	IN_A	Clockwise input. CMOS compatible
7	PWM	PWM input. CMOS compatible.
8	CS	Output of current sense. This output delivers a current proportional to the motor current, if CS_DIS is low or left open. The information can be read back as an analog voltage across an external resistor.
9	$EN_B/DIAG_B$	Status of high-side and low-side switches B; Open drain output. This pin must be connected to an external pull up resistor. When externally pulled low, it disables half-bridge B. In case of fault detection (thermal shutdown of a high-side FET or excessive ON-state voltage drop across a low-side FET), this pin is pulled low by the device (see *Table 13: Truth table in fault conditions (detected on OUTA)*.
10	IN_B	Counter clockwise input. CMOS compatible
11	CP	Connection to the gate of the external MOS used for the reverse battery protection
15, 16, 21	OUT_B, Heat Slug3	Source of high-side switch B / drain of low-side switch B, power connection to the motor
26, 27, 28	GND_A	Source of low-side switch A and power ground(1)
18, 19, 20	GND_B	Source of low-side switch B and power ground(1)

1. GNDA and GNDB must be externally connected together

Table 3. Block descriptions(1)

Name	Description
Logic control	Allows the turn-on and the turn-off of the high-side and the low-side switches according to the *Table 12*.
Overvoltage + undervoltage	Shut down the device outside the range [4.5 V to 24 V] for the battery voltage.
High-side, low-side and clamp voltage	Protect the high-side and the low-side switches from the high-voltage on the battery line in all configuration for the motor.
High-side and low-side driver	Drive the gate of the concerned switch to allow a proper $R_{DS(on)}$ for the leg of the bridge.
Linear current limiter	Limits the motor current, by reducing the high-side switch gate-source voltage when short-circuit to ground occurs.
High-side and low-side overtemperature protection	In case of short-circuit with the increase of the junction's temperature, it shuts down the concerned driver to prevent its degradation and to protect the die.
Low-side overload detector	Detects when low-side current exceeds shutdown current and latches off the concerned low-side.

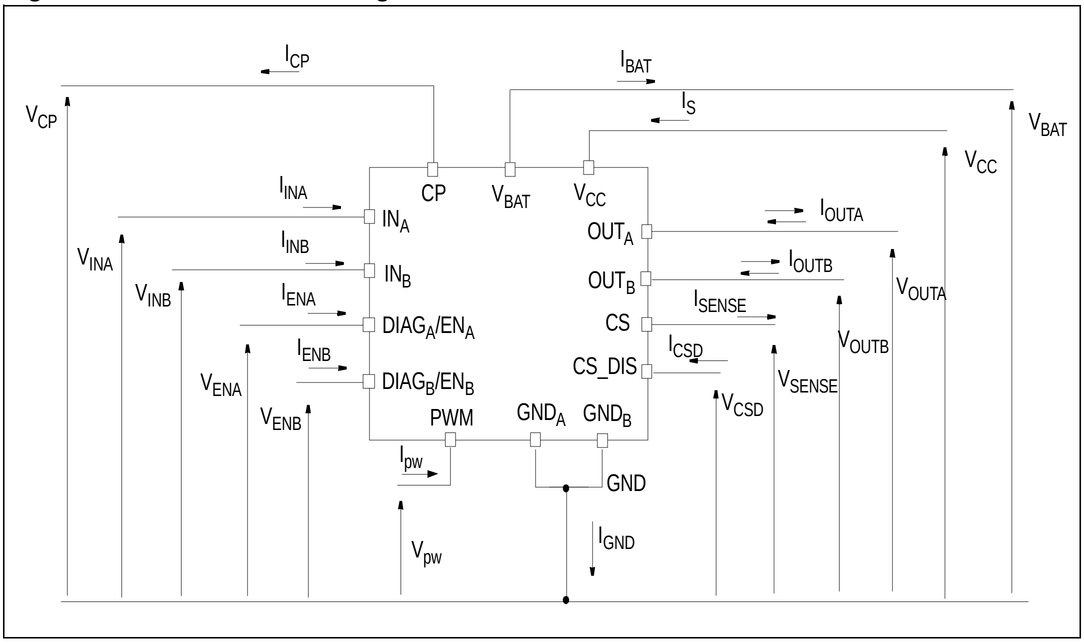
Table 3. Block descriptions[1] (continued)

Name	Description
Charge pump	Provides the voltage necessary to drive the gate of the external PowerMOS used for the reverse polarity protection
Fault detection	Signalizes an abnormal condition of the switch (output shorted to ground or output shorted to battery) by pulling down the concerned ENx/DIAGx pin.
Power limitation	Limits the power dissipation of the high-side driver inside safe range in case of short to ground condition.

1. See *Figure 1*

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stressing the device above the rating listed in the “absolute maximum ratings” table may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE program and other relevant quality document.

Table 4. Absolute maximum rating

Symbol	Parameter	Value	Unit
V_{BAT}	Maximum battery voltage(1)	-16 +41	V V
V_{CC}	Maximum bridge supply voltage	+ 41	V
I_{max}	Maximum output current (continuous)	30	A
I_R	Reverse output current (continuous)	-30	A
I_{IN}	Input current (IN_A and IN_B pins)	+/- 10	mA
I_{EN}	Enable input current ($DIAG_A/EN_A$ and $DIAG_B/EN_B$ pins)	+/- 10	mA
I_{pw}	PWM input current	+/- 10	mA
I_{CP}	CP output current	+/- 10	mA
I_{CS_DIS}	CS_DIS input current	+/- 10	mA

Table 4. Absolute maximum rating (continued)

Symbol	Parameter	Value	Unit
V_{CS}	Current sense maximum voltage	V_{CC} - 41 +V_{CC}	V V
V_{ESD}	Electrostatic discharge (human body model: R = 1.5 kΩ, C = 100 pF)	2	kV
T_c	Case operating temperature	-40 to 150	°C
T_{STG}	Storage temperature	-55 to 150	°C

1. This applies with the n-channel MOSFET used for the reverse battery protection. Otherwise V_{BAT} has to be shorted to V_{CC}.

2.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	Max. value	Unit
$R_{thj\text{-}case}$	Thermal resistance junction-case HSD	1.7	°C/W
	Thermal resistance junction-case LSD	3.2	°C/W
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient	See *Figure 18*	°C/W

2.3 Electrical characteristics

Values specified in this section are for 8 V < V_{CC} < 21 V, -40 °C < T_j < 150 °C, unless otherwise specified.

Table 6. Power section

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{CC}	Operating bridge supply voltage		5.5		24	V
I_S	Supply current	OFF-state with all fault cleared and ENx = 0 V (standby): $IN_A = IN_B$ = PWM = 0; T_j = 25 °C; V_{CC} = 13 V $IN_A = IN_B$ = PWM = 0 OFF-state (no standby): $IN_A = IN_B$ = PWM = 0; ENx = 5 V		10	15 60 6	µA µA mA
		ON-state: IN_A or IN_B = 5 V, no PWM IN_A or IN_B = 5 V, PWM = 20 kHz		4	8 8	mA mA
R_{ONHS}	Static high-side resistance	I_{OUT} = 15 A; T_j = 25 °C		12.0		mΩ
		I_{OUT} = 15 A; T_j = - 40 °C to 150 °C			26.5	
R_{ONLS}	Static low-side resistance	I_{OUT} = 15 A; T_j = 25 °C		6.0		mΩ
		I_{OUT} = 15 A; T_j = - 40 °C to 150 °C			11.5	
V_f	High-side free-wheeling diode forward voltage	I_f = 15 A, T_j = 150 °C		0.6	0.8	V
$I_{L(off)}$	High-side OFF-state output current (per channel)	T_j = 25 °C; $V_{OUTX} = EN_X$ = 0 V; V_{CC} = 13 V			3	µA
		T_j = 125 °C; $V_{OUTX} = EN_X$ = 0 V; V_{CC} = 13 V			5	

Table 7. Logic inputs (IN_A, IN_B, EN_A, EN_B, PWM, CS_DIS)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IL}	Low-level input voltage	Normal operation ($DIAG_X/EN_X$ pin acts as an input pin)			0.9	V
V_{IH}	High-level input voltage	Normal operation ($DIAG_X/EN_X$ pin acts as an input pin)	2.1			V
I_{INL}	Low-level input current	V_{IN} = 0.9 V	1			µA
I_{INH}	High-level input current	V_{IN} = 2.1 V			10	µA
V_{IHYST}	Input hysteresis voltage	Normal operation ($DIAG_X/EN_X$ pin acts as an input pin)	0.15			V

Table 7. Logic inputs (IN_A, IN_B, EN_A, EN_B, PWM, CS_DIS) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{ICL}	Input clamp voltage	I_{IN} = 1 mA	5.5	6.3	7.5	V
		I_{IN} = -1 mA	-1.0	-0.7	-0.3	
V_{DIAG}	Enable low-level output voltage	Fault operation ($DIAG_X/EN_X$ pin acts as an output pin); I_{EN} = 1 mA			0.4	V

Table 8. Switching (V_{CC} = 13 V, R_{LOAD} = 0.87 Ω, Tj = 25 °C)

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
f	PWM frequency		0		20	kHz
$t_{d(on)}$	HSD rise time	Input rise time < 1µs (see *Figure 9*)			250	µs
$t_{d(off)}$	HSD fall time	Input rise time < 1µs (see *Figure 9*)			250	µs
t_r	LSD rise time	(see *Figure 8*)		1	2	µs
t_f	LSD fall time	(see *Figure 8*)		1	2	µs
t_{DEL}	Delay time during change of operating mode	(see *Figure 7*)	200	400	1600	µs
t_{rr}	High-side free wheeling diode reverse recovery time	(see *Figure 10*)		110		ns
I_{RM}	Dynamic cross-conduction current	I_{OUT} = 15 A (see *Figure 10*)		2		A

Table 9. Protection and diagnostic

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
V_{USD}	V_{CC} undervoltage shutdown			4.5	5.5	V
$V_{USDhyst}$	V_{CC} undervoltage shutdown hysteresis			0.5		V
V_{OV}	V_{CC} overvoltage shutdown		24	27	30	V
I_{LIM_H}	High-side current limitation		30	50	70	A
I_{SD_LS}	Low-side shutdown current		70	115	160	A
V_{CLPHS}(1)	High-side clamp voltage (V_{CC} to OUT_A = 0 or OUT_B = 0)	I_{OUT} = 15 A	43	48	54	V
V_{CLPLS}(1)	Low-side clamp voltage (OUT_A = V_{CC} or OUT_B = V_{CC} to GND)	I_{OUT} = 15 A	27	30	33	V
T_{TSD}(2)	Thermal shutdown temperature	V_{IN} = 2.1 V	150	175	200	°C

Table 9. Protection and diagnostic (continued)

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
T_{TSD_LS}	Low-side thermal shutdown temperature	V_{IN} = 0 V	150	175	200	°C
T_{TR}(3)	Thermal reset temperature		135			°C
T_{HYST}(3)	Thermal hysteresis		7	15		°C

1. The device is able to pass the ESD and ISO pulse requirements as specified in the *Table 15*.
2. T_{TSD} is the minimum threshold temperature between HS and LS
3. Valid for both HSD and LSD

Table 10. Current sense (8 V < V_{CC} < 21 V)

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
K_0	I_{OUT}/I_{SENSE}	I_{OUT} = 3 A, V_{SENSE} = 0.5 V, T_j = - 40 °C to 150°C	4670	7110	10110	
dK_0/K_0	Analog current sense ratio drift	I_{OUT} = 3 A; V_{SENSE} = 0.5 V, T_j = -40 °C to 150 °C	-19		19	%
K_1	I_{OUT}/I_{SENSE}	I_{OUT} = 8 A, V_{SENSE} = 1.3V, T_j = - 40 °C to 150°C	6060	7030	8330	
dK_1/K_1	Analog current sense ratio drift	I_{OUT} = 8 A; V_{SENSE} = 1.3V, T_j = -40 °C to 150 °C	-14		14	%
K_2	I_{OUT}/I_{SENSE}	I_{OUT} = 15 A, V_{SENSE} = 2.4 V, T_j = - 40 °C to 150°C	6070	6990	7810	
dK_2/K_2	Analog current sense ratio drift	I_{OUT} = 15 A; V_{SENSE} = 2.4 V, T_j = -40 °C to 150 °C	-12		12	%
K_3	I_{OUT}/I_{SENSE}	I_{OUT} = 25 A, V_{SENSE} = 4 V, T_j = - 40 °C to 150°C	6000	6940	7650	
dK_3/K_3	Analog current sense ratio drift	I_{OUT} =25 A; V_{SENSE} = 4 V, T_j = -40 °C to 150 °C	-12		12	%
V_{SENSE}	Max analog sense output voltage	I_{OUT} = 15 A, R_{SENSE} = 1.1 kΩ	5			V
I_{SENSEO}	Analog sense leakage current	I_{OUT} = 0 A, V_{SENSE} = 0 V, V_{CSD} = 5 V, V_{IN} = 0 V, T_j = - 40 to 150°C	0		5	µA
		I_{OUT} = 0 A, V_{SENSE} = 0 V, V_{CSD} = 0 V, V_{IN} = 5 V, T_j = - 40 to 150°C	0		100	
$t_{DSENSEH}$	Delay response time from falling edge of CS_DIS pin	V_{IN} = 5 V, V_{SENSE} < 4 V, I_{OUT} = 8 A, I_{SENSE} = 90% of $I_{SENSEmax}$ (see fig *Figure 13*)			50	µs
$t_{DSENSEL}$	Delay response time from rising edge of CS_DIS pin	V_{IN} = 5 V, V_{SENSE} < 4 V, I_{OUT} = 8 A, I_{SENSE} = 10% of $I_{SENSEmax}$ (see fig *Figure 13*)			20	µs

Table 11. Charge pump

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
V_{CP}	Charge pump output voltage	$EN_X = 5$ V	$V_{CC} + 5$		$V_{CC} + 10$	V
		$EN_X = 5$ V, $V_{CC} = 4.5$ V		10.5		
I_{BAT}	Charge pump standby current	$EN_A = EN_B = 0$ V		200		nA

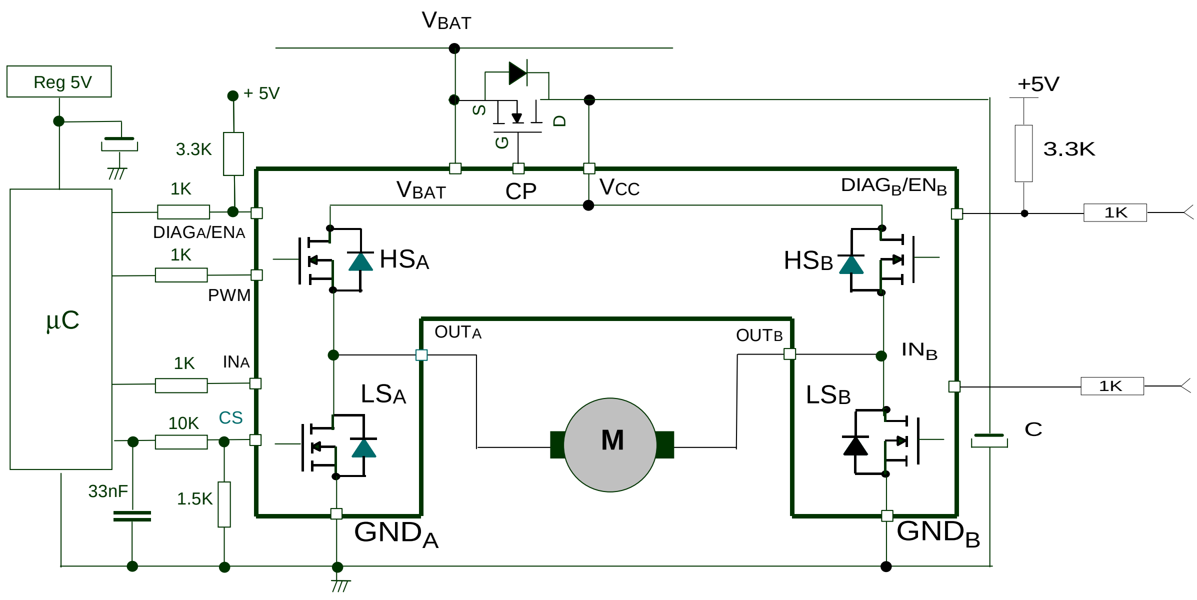
2.4 Waveforms and truth table

In normal operating conditions the $DIAG_X/EN_X$ pin is considered as an input pin by the device. This pin must be externally pulled-high
PWM pin usage: in all cases, a “0” on the PWM pin turns-off both LS_A and LS_B switches. When PWM rises back to “1”, LS_A or LS_B turn-on again depending on the input pin state.

Table 12. Truth table in normal operating conditions

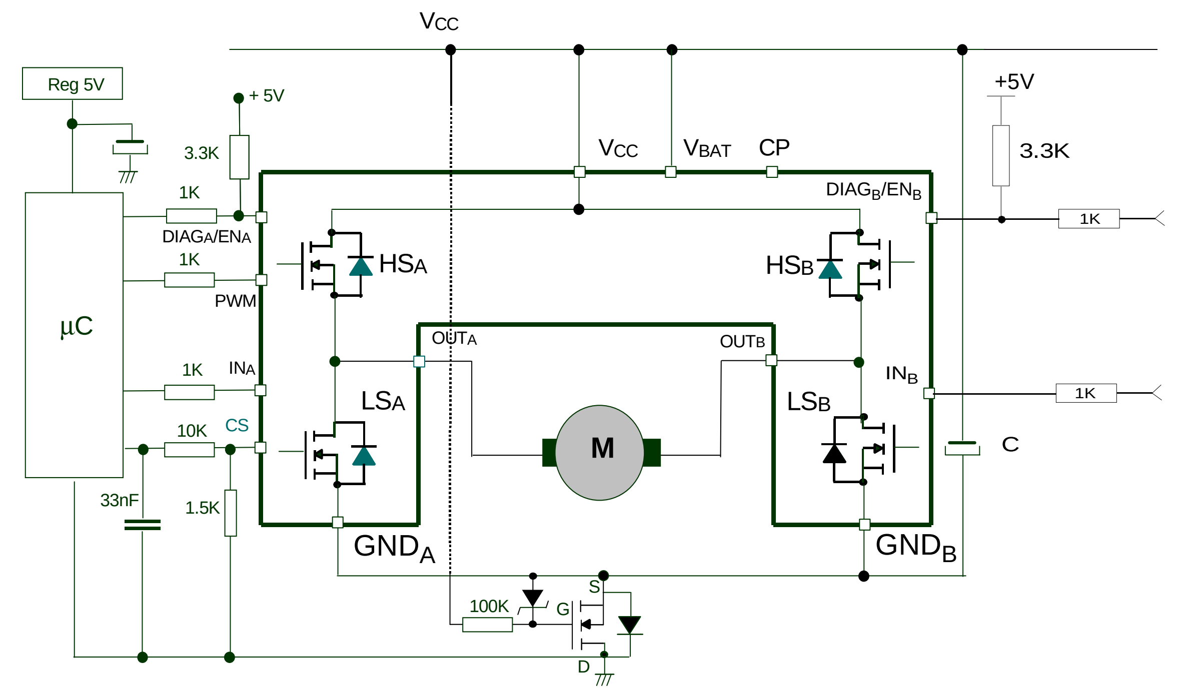
IN_A	IN_B	$DIAG_A/EN_A$	$DIAG_B/EN_B$	OUT_A	OUT_B	CS ($V_{CSD} = 0$ V)	Operating mode
1	1	1	1	H	H	High imp.	Brake to V_{CC}
1	0	1	1	H	L	$I_{SENSE} = I_{OUT}/K$	Clockwise (CW)
0	1	1	1	L	H	$I_{SENSE} = I_{OUT}/K$	Counterclockwise (CCW)
0	0	1	1	L	L	High imp.	Brake to GND

Figure 4. Typical application circuit for DC to 20 kHz PWM operation with reverse battery protection (option A)



Note:
The external N-channel Power MOSFET used for the reverse battery protection should have the following characteristics:
- BVdss > 20 V (for a reverse battery of -16 V);
- $R_{DS(on)}$ < 1/3 of H-bridge total $R_{DS(on)}$
- Standard Logic Gate Driving

Figure 5. Typical application circuit for DC to 20 kHz PWM operation with reverse battery protection (option B)



Note:
The value of the blocking capacitor (C) depends on the application conditions and defines voltage and current ripple onto supply line at PWM operation. Stored energy of the motor inductance may flyback into the blocking capacitor, if the bridge driver goes into 3-state. This causes a hazardous overvoltage if the capacitor is not big enough. As basic orientation, 500 µF per 10 A load current is recommended.

Table 13. Truth table in fault conditions (detected on OUT_A)

IN_A	IN_B	$DIAG_A/EN_A$	$DIAG_B/EN_B$	OUT_A	OUT_B	CS (V_{CSD}=0V)
1	1	0	1	OPEN	H	High impedance
	0				L	
0	1				H	I_{OUTB}/K
	0				L	High impedance
X	X		0		OPEN	

Fault Information   Protection Action

Note: *In normal operating conditions the $DIAG_X/EN_X$ pin is considered as an input pin by the device. This pin must be externally pulled high.*

In case of a fault condition the $DIAG_X/EN_X$ pin is considered as an output pin by the device.

The fault conditions are:

- overtemperature on one or both high-sides (for example, if a short to ground occurs as it could be the case described in line 1 and 2 in the *Table 14*);
- Short to battery condition on the output (saturation detection on the low-side Power MOSFET).

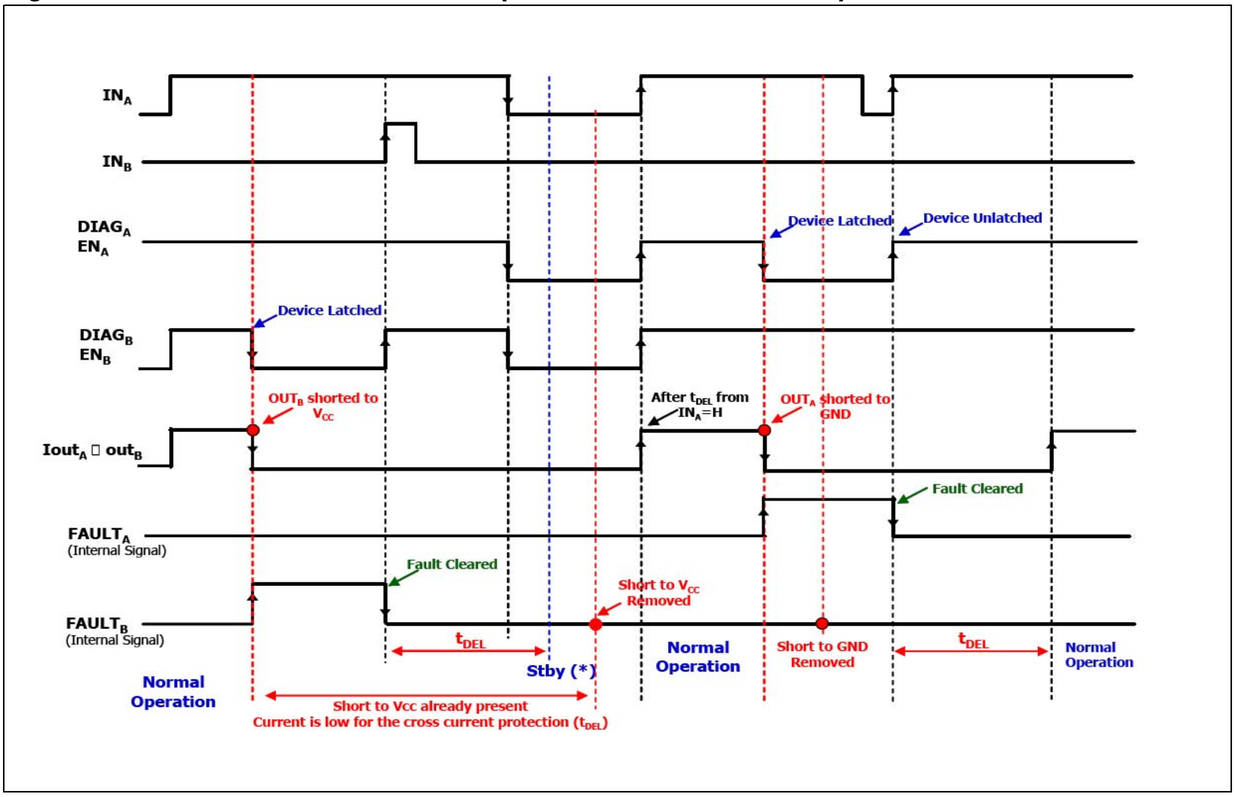
Possible origins of fault conditions may be:

- OUT_A is shorted to ground. It follows that, high-side A is in overtemperature state.
- OUT_A is shorted to V_{CC}. It follow that, low-side Power MOSFET is in saturation state.

When a fault condition is detected, the user can know which power element is in fault by monitoring the IN_A, IN_B, $DIAG_A/EN_A$ and $DIAG_B/EN_B$ pins.

In any case, when a fault is detected, the faulty leg of the bridge is latched off. To turn-on the respective output (OUT_X) again, the input signal must rise from low-level to high-level.

Figure 6. Behavior in fault condition (how a fault can be cleared)



Note: In case of the fault condition is not removed, the procedure for unlatching and sending the device in Stby mode is:

- Clear the fault in the device (toggle: INA if ENA=0 or INB if ENB=0)

- Pull low all inputs, PWM and Diag/EN pins within tDEL.

If the Diag/En pins are already low, PWM=0, the fault can be cleared simply toggling the input. The device enters in stby mode as soon as the fault is cleared.

Table 14. Electrical transient requirements (part 1)

ISO T/R 7637/1 Test Pulse	Test level				
	I	II	III	IV	Delay and impedance
1	-25 V	-50 V	-75 V	-100 V	2 ms, 10 Ω
2	+25 V	+50 V	+75 V	+100 V	0.2 ms, 10 Ω
3a	-25 V	-50 V	-100 V	-150 V	0.1 µs, 50 Ω
3b	+25 V	+50 V	+75 V	+100 V	0.1 µs, 50 Ω
4	-4 V	-5 V	-6 V	-7 V	100 ms, 0.01 Ω
5	+26.5 V	+46.5 V	+66.5 V	+86.5 V	400 ms, 2 Ω

Table 15. Electrical transient requirements (part 2)

ISO T/R 7637/1 Test Pulse	Test levels			
	I	II	III	IV
1	C	C	C	C
2	C	C	C	C
3a	C	C	C	C
3b	C	C	C	C
4	C	C	C	C
5	C	E	E	E

Table 16. Electrical transient requirements (part 3)

Class	Contents
C	All functions of the device are performed as designed after exposure to disturbance.
E	One or more functions of the device are not performed as designed after exposure to disturbance and cannot be returned to proper operation without replacing the device.

2.5 Reverse battery protection

Against reverse battery condition the charge pump feature allows to use an external N-channel MOSFET connected as shown in the typical application circuit (see *Figure 4*).

As alternative option, a N-channel MOSFET connected to GND pin can be used (see typical application circuit in figure *Figure 5*).

With this configuration we recommend to short V_{BAT} pin to V_{CC}.

The device sustains no more than -30 A in reverse battery conditions because of the two body diodes of the Power MOSFETs. Additionally, in reverse battery condition the I/Os of VNH5019A-E is pulled-down to the V_{CC} line (approximately -1.5 V). Series resistor must be inserted to limit the current sunk from the microcontroller I/Os. If I_{Rmax} is the maximum target reverse current through microcontroller I/Os, series resistor is:

$$R = \frac{V_{IOs} - V_{CC}}{I_{Rmax}}$$

Figure 7. Definition of the delay times measurement

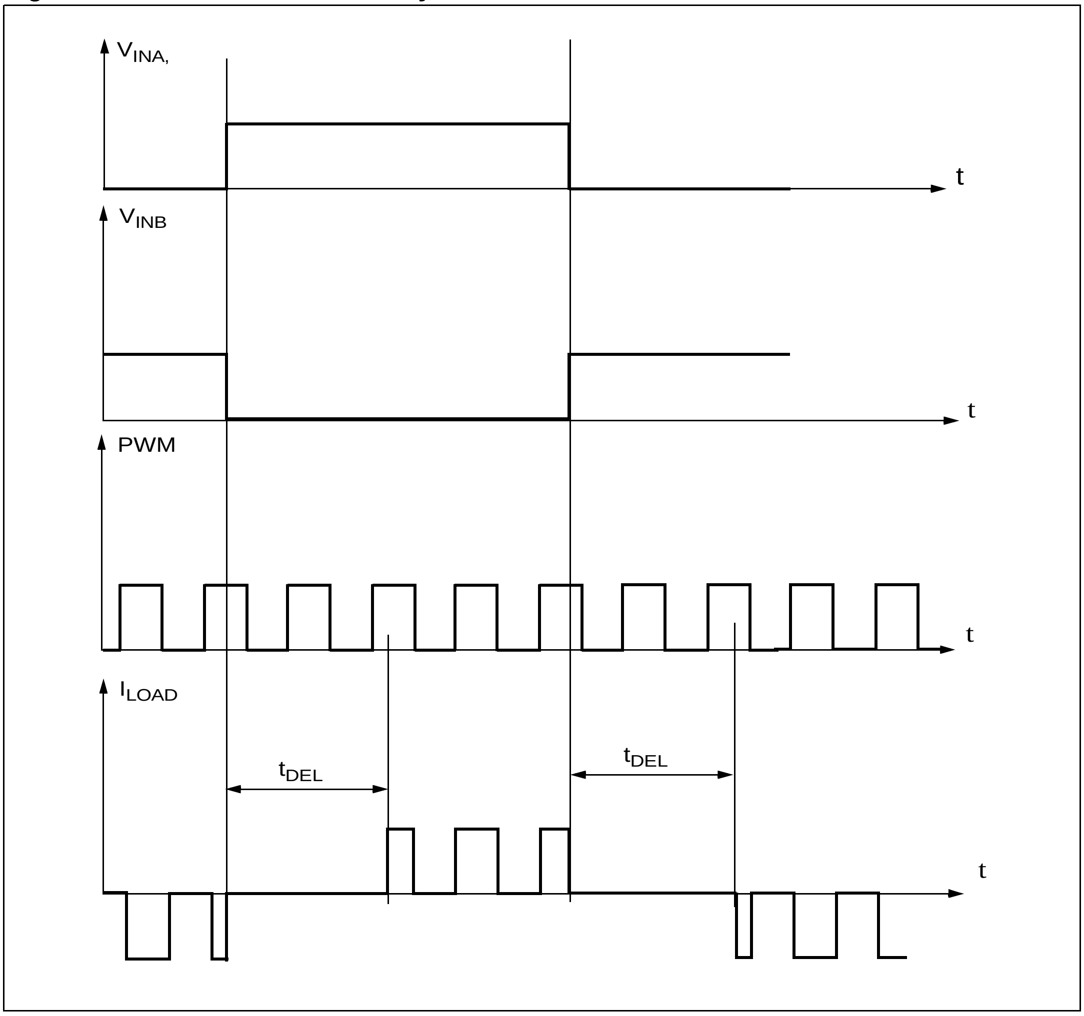


Figure 8. Definition of the low-side switching times

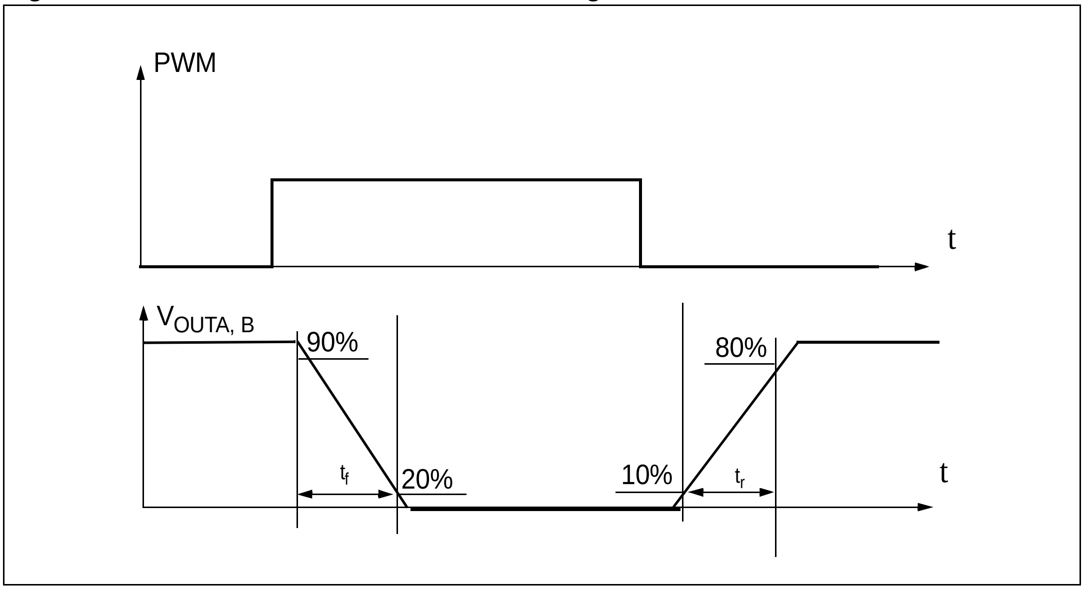


Figure 9. Definition of the high-side switching times

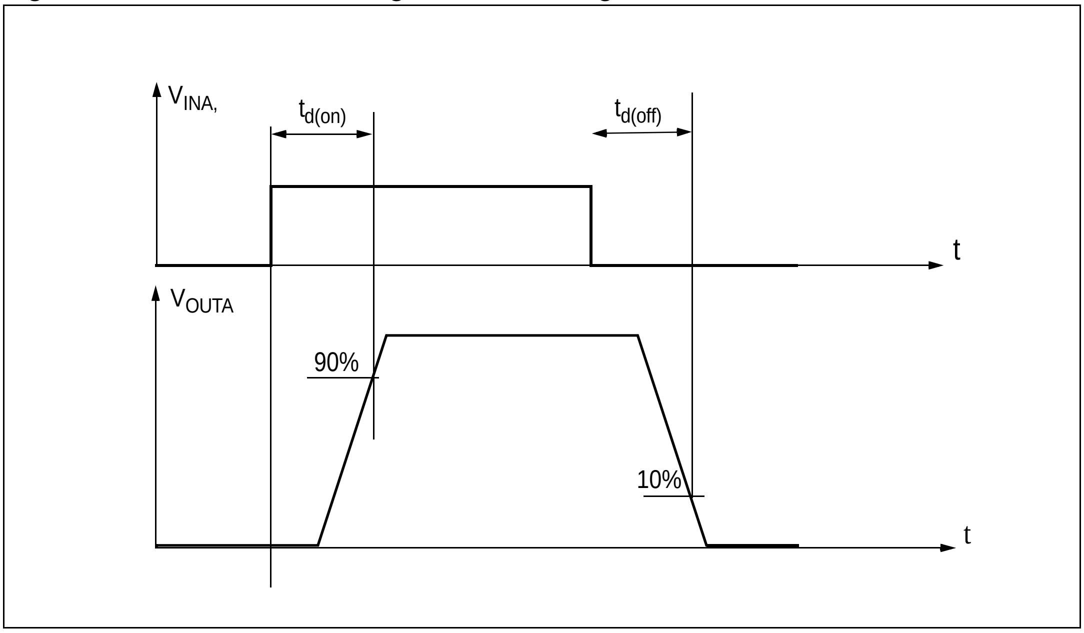


Figure 10. Definition of dynamic cross conduction current during a PWM operation

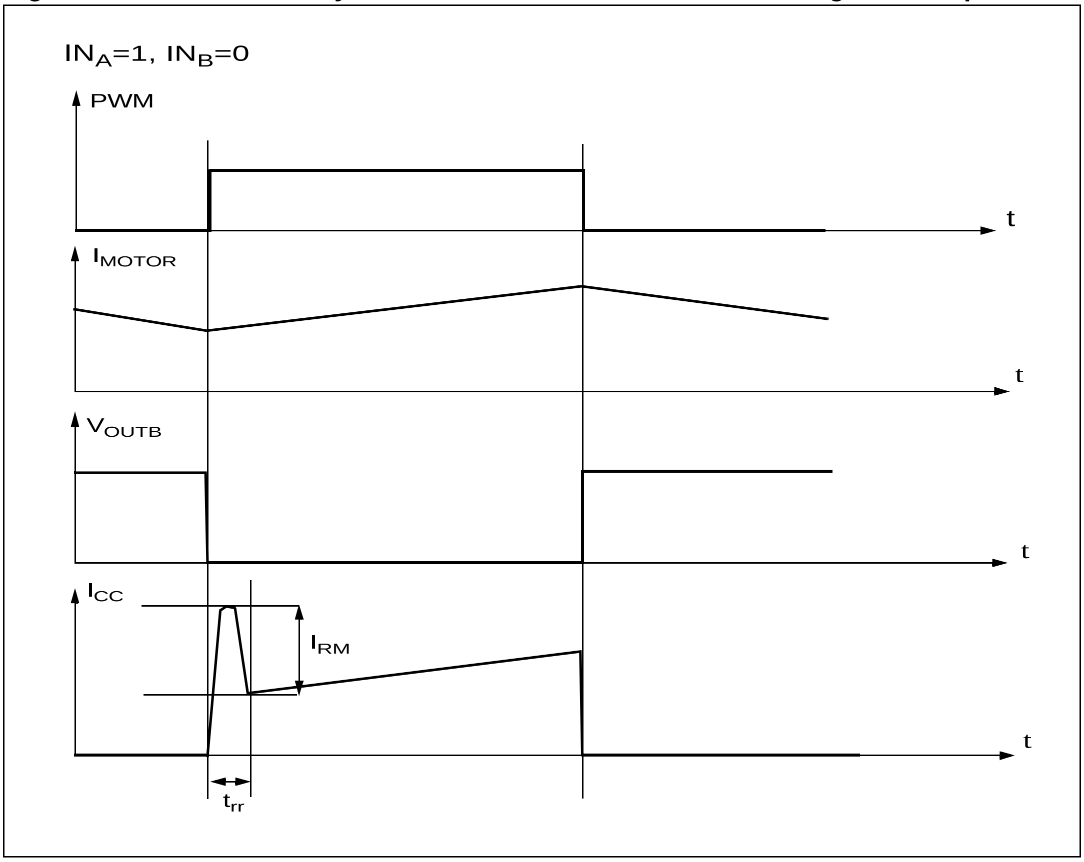


Figure 11. Waveforms in full bridge operation (part 1)

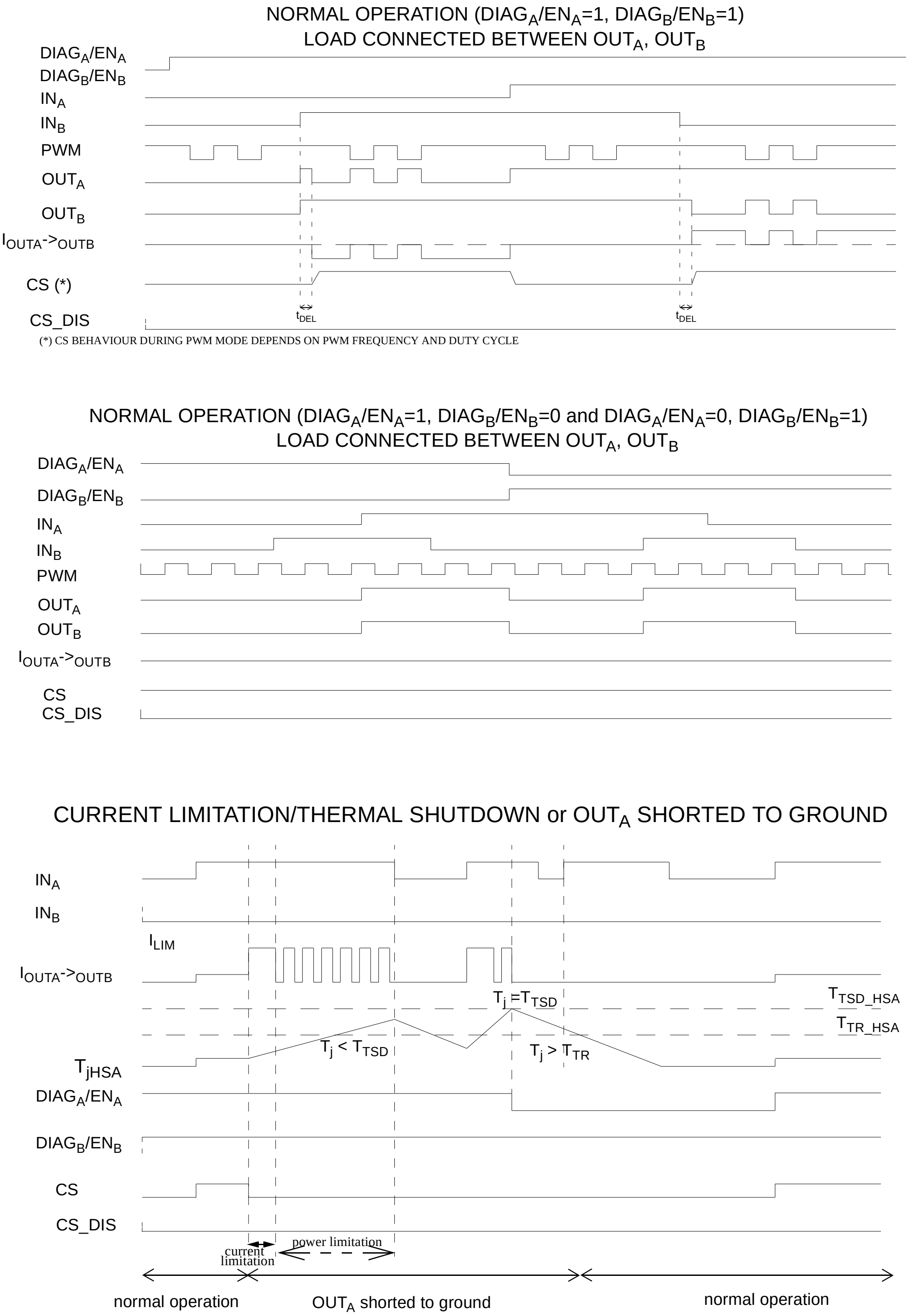


Figure 12. Waveforms in full bridge operation (part 2)

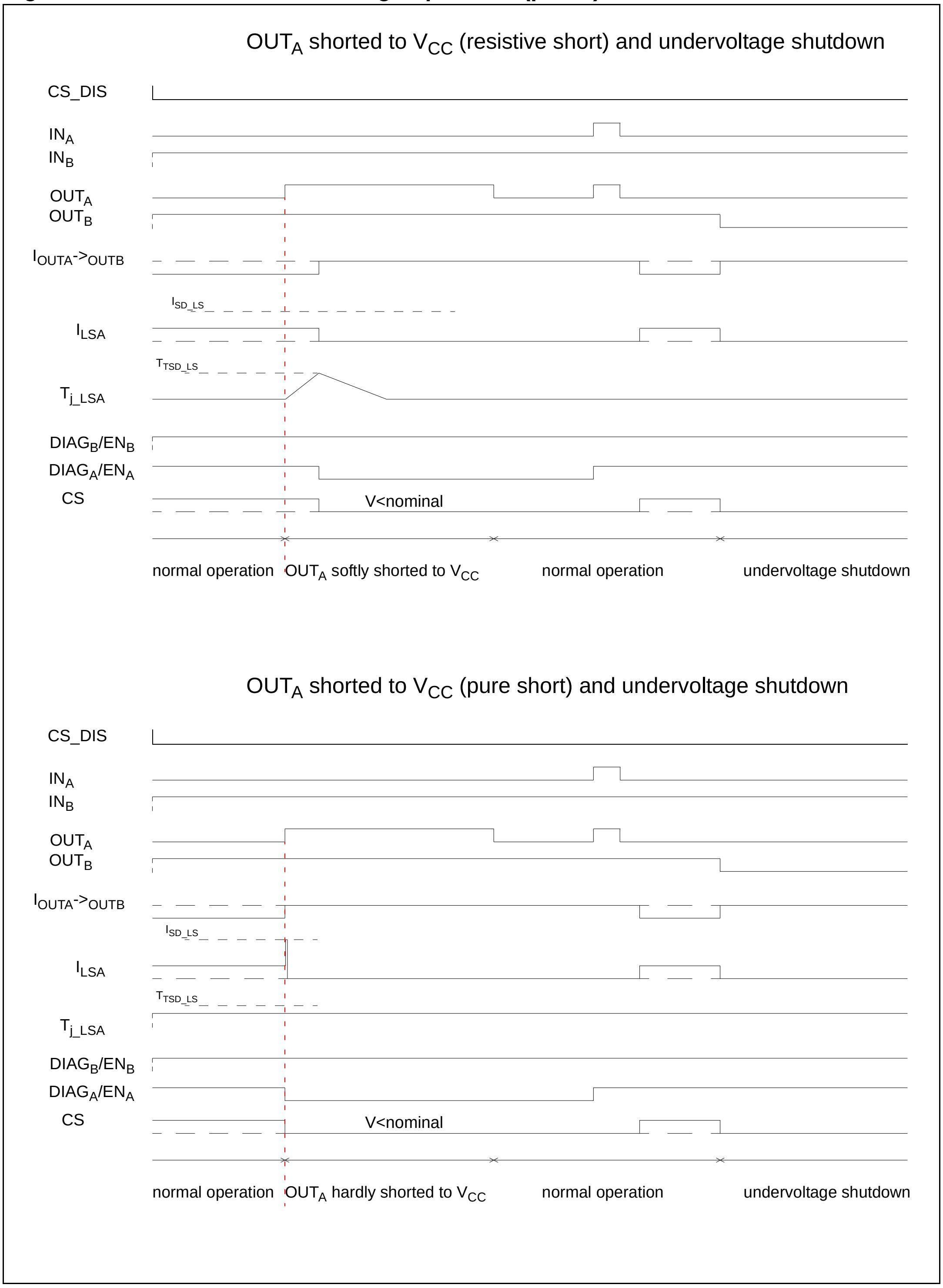
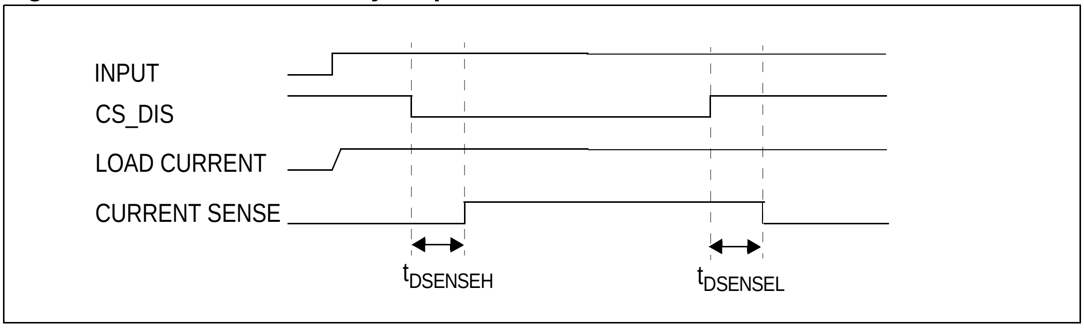
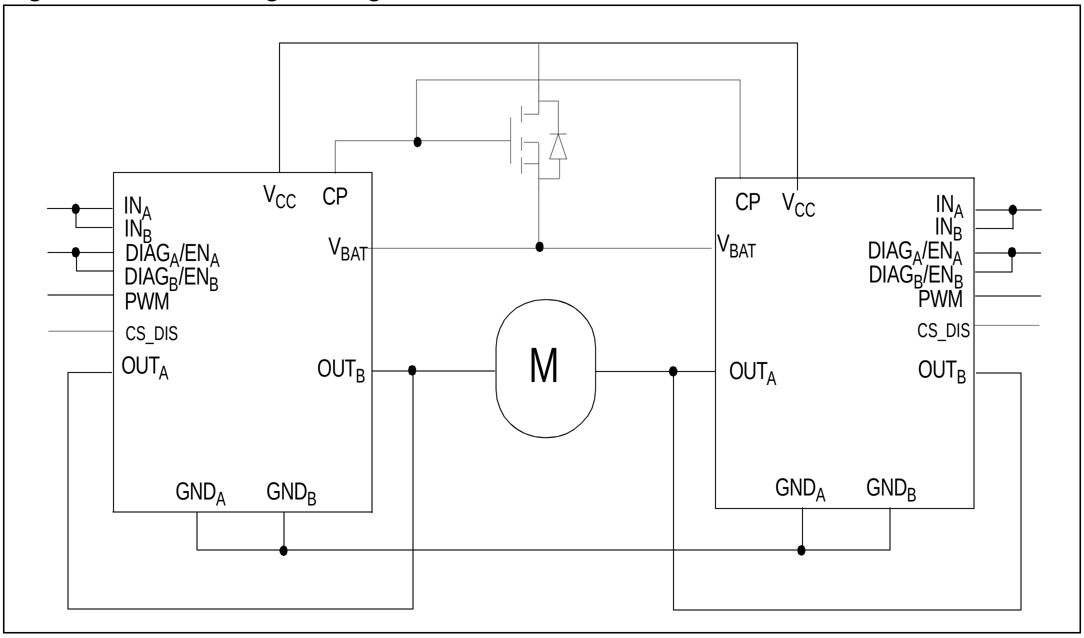


Figure 13. Definition of delay response time of sense current



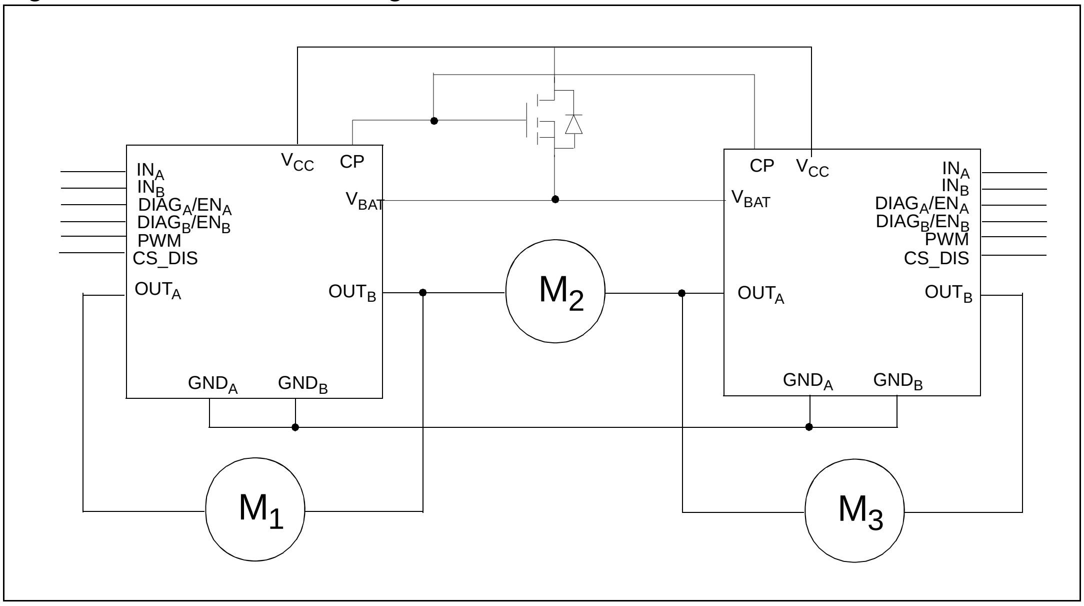
The VNH5019A-E can be used as a high power half-bridge driver achieving an on- resistance per leg of 9.5 mΩ. The figure below shows the suggested configuration:

Figure 14. Half-bridge configuration



The VNH5019A-E can easily be designed in multi-motors driving applications such as seat positioning systems where only one motor must be driven at a time. $DIAG_X/EN_X$ pins allow to put unused half-bridges in high-impedance. The figure below shows the suggested configuration:

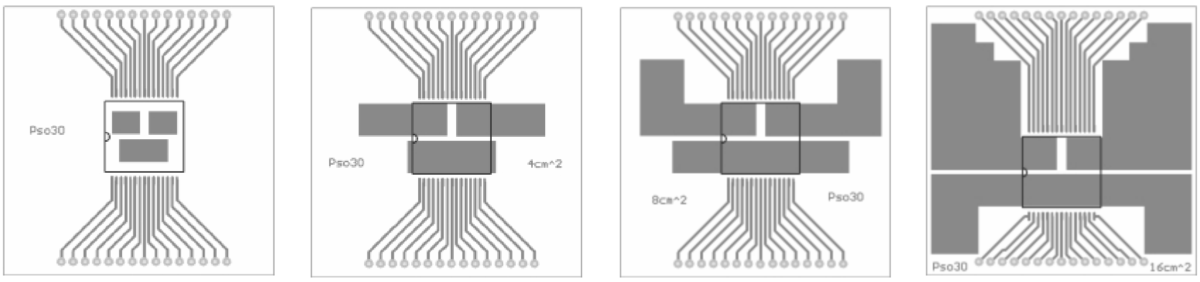
Figure 15. Multi-motors configuration



3 Package and PCB thermal data

3.1 MultiPowerSO-30 thermal data

Figure 16. MultiPowerSO-30™ PC board



Note:
Layout condition of Rth and Zth measurements (PCB FR4 area= 58 mm x 58 mm, PCB thickness=2 mm, Cu thickness=35 mm, Copper areas: from minimum pad lay-out to 16 cm^2).

Figure 17. Chipset configuration

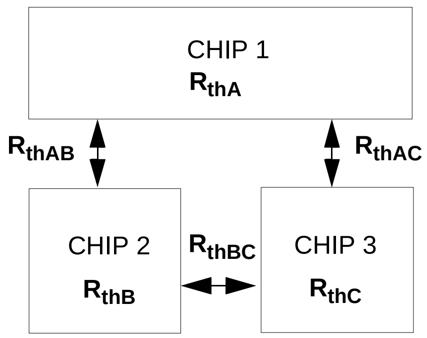
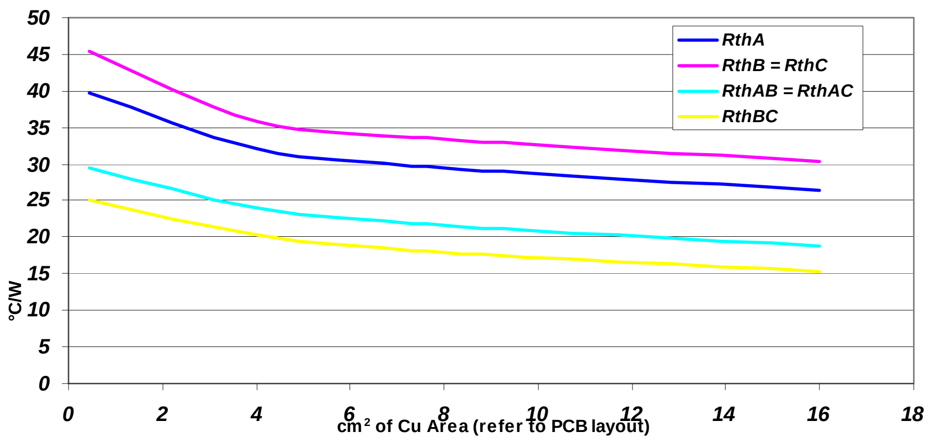


Figure 18. Auto and mutual $R_{thj-amb}$ vs PCB copper area in open box free air condition



3.1.1 Thermal calculation in clockwise and anti-clockwise operation in steady-state mode

Table 17. Thermal calculation in clockwise and anti-clockwise operation in steady-state mode

Chip 1	Chip 2	Chip 3	Tjchip1	Tjchip2	Tjchip3
ON	OFF	ON	$P_{dchip1} \cdot R_{thA} + P_{dchip3} \cdot R_{thAC} + T_{amb}$	$P_{dchip1} \cdot R_{thAB} + P_{dchip3} \cdot R_{thBC} + T_{amb}$	$P_{dchip1} \cdot R_{thAC} + P_{dchip3} \cdot R_{thC} + T_{amb}$
ON	ON	OFF	$P_{dchip1} \cdot R_{thA} + P_{dchip2} \cdot R_{thAB} + T_{amb}$	$P_{dchip1} \cdot R_{thAB} + P_{dchip2} \cdot R_{thB} + T_{amb}$	$P_{dchip1} \cdot R_{thAC} + P_{dchip2} \cdot R_{thBC} + T_{amb}$
ON	OFF	OFF	$P_{dchip1} \cdot R_{thA} + T_{amb}$	$P_{dchip1} \cdot R_{thAB} + T_{amb}$	$P_{dchip1} \cdot R_{thAC} + T_{amb}$
ON	ON	ON	$P_{dchip1} \cdot R_{thA} + (P_{dchip2} + P_{dchip3}) \cdot R_{thAB} + T_{amb}$	$Pdchip2 \cdot R_{thB} + P_{dchip1} \cdot R_{thAB} + P_{dchip3} \cdot R_{thBC} + T_{amb}$	$P_{dchip1} \cdot R_{thAB} + P_{dchip2} \cdot R_{thBC} + P_{dchip3} \cdot R_{thC} + T_{amb}$

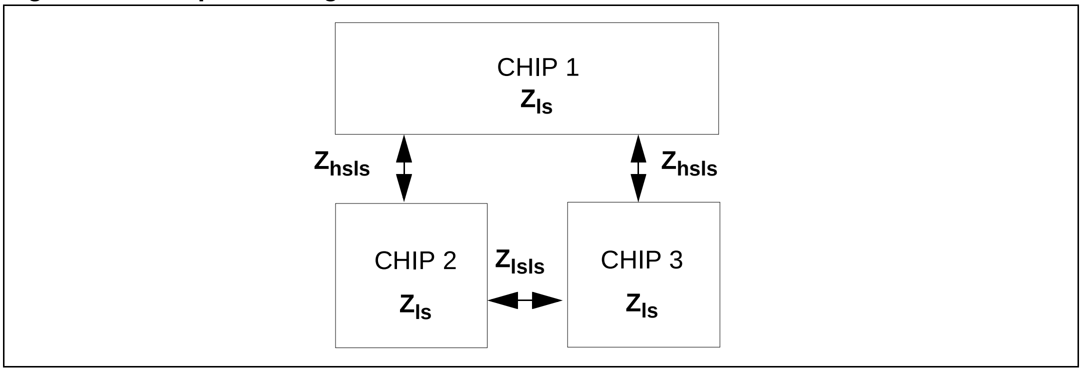
3.1.2 Thermal calculation in transient mode

$T_{hs} = P_{dhs} \cdot Z_{hs} + Z_{hsls} \cdot (Pd_{lsA} + Pd_{lsB}) + T_{amb}$

$T_{lsA} = Pd_{lsA} \cdot Z_{ls} + Pd_{hs} \cdot Z_{hsls} + Pd_{lsB} \cdot Z_{hsls} + T_{amb}$

$T_{lsB} = Pd_{lsB} \cdot Z_{ls} + Pd_{hs} \cdot Z_{hsls} + Pd_{ls}A \cdot Z_{hsls} + T_{amb}$

Figure 19. Chipset configuration



Equation 1: pulse calculation formula

$$Z_{TH\delta} = R_{TH} \cdot \delta + Z_{THtp}(1 - \delta)$$

where $\delta = t_p / T$

Figure 20. MultiPowerSO-30 HSD thermal impedance junction ambient single pulse

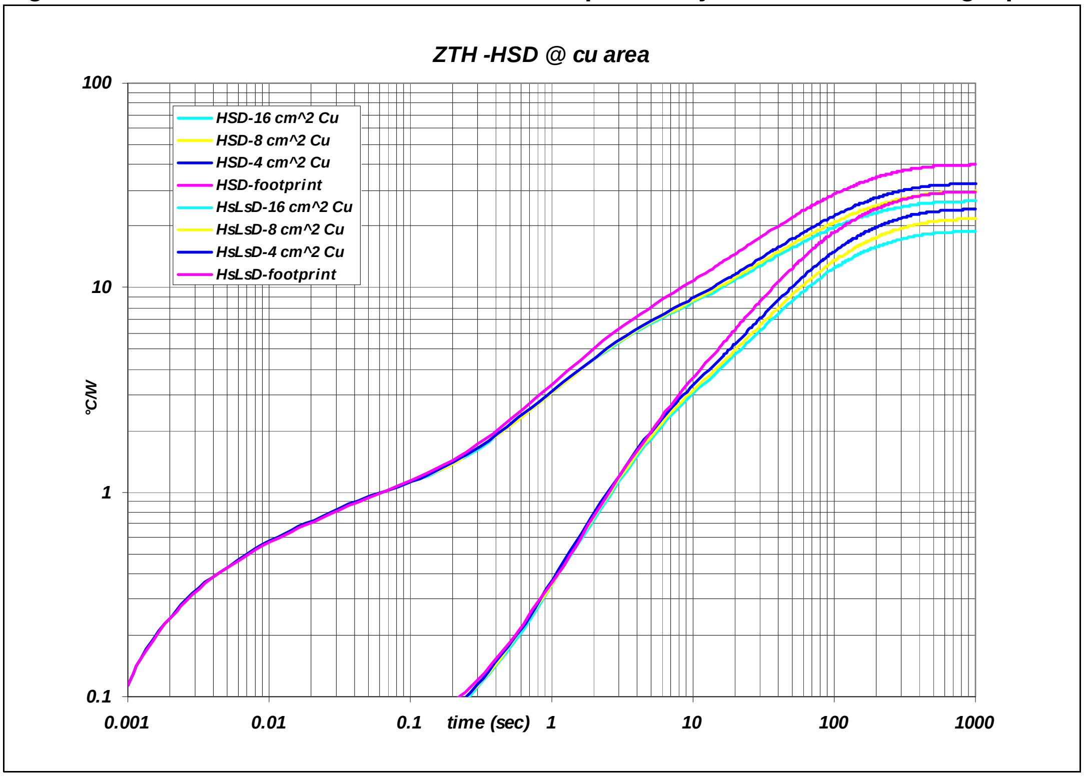


Figure 21. MultiPowerSO-30 LSD thermal impedance junction ambient single pulse

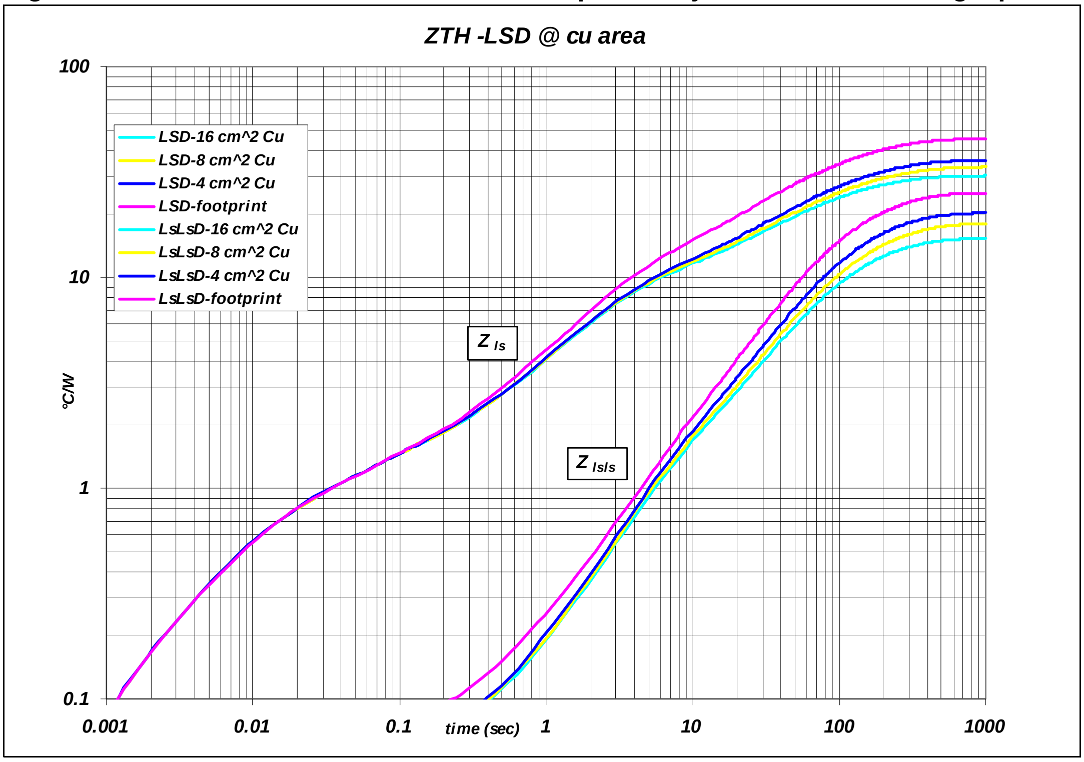


Figure 22. Thermal fitting model of an H-bridge in MultiPowerSO-30

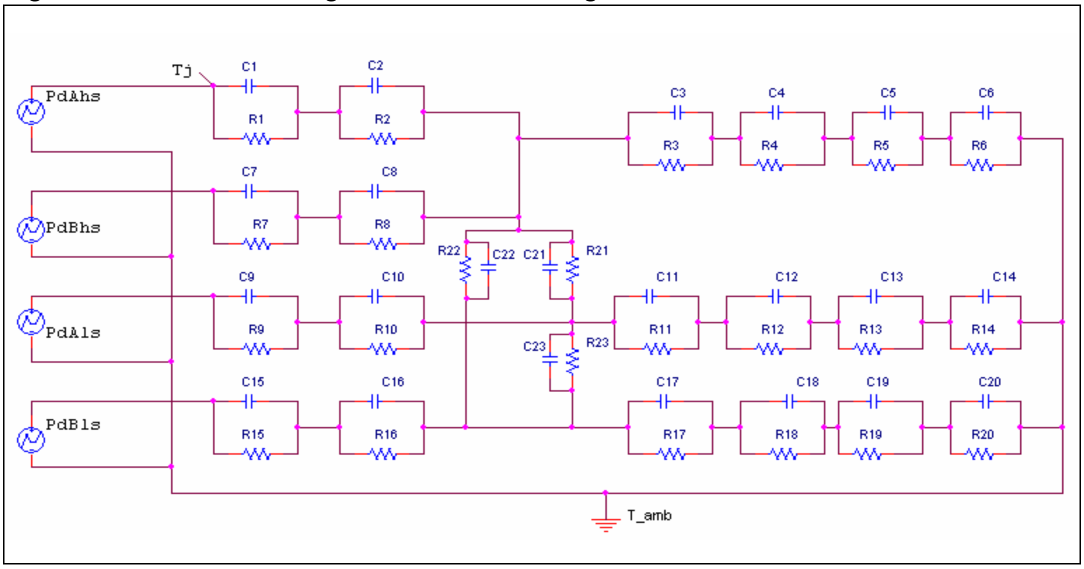


Table 18. Thermal parameters(1)

Area/island (cm^2)	Footprint	4	8	16
R1 = R7 (°C/W)	0.1			
R2 = R8 (°C/W)	0.3			
R3 = R10 = R16 (°C/W)	0.5			
R4 (°C/W)	6			
R5 (°C/W)	30	24	24	24
R6 (°C/W)	56	52	42	32
R9 = R15 (°C/W)	0.05			
R11 = R17 (°C/W)	0.7			
R12 = R18 (°C/W)	10			
R13 = R19 (°C/W)	36	26	26	26
R14 = R20 (°C/W)	56	42	36	28
R21 = R22 (°C/W)	35	25	25	25
R23 (°C/W)	160	150	150	150
C1 = C7 = C9 = C15 (W.s/°C)	0.005			
C2 = C8 (W.s/°C)	0.01			
C3 (W.s/°C)	0.03			
C4 (W.s/°C)	0.4			
C5 (W.s/°C)	1.5	2	2	2
C6 (W.s/°C)	3	4	5	6
C10 = C16 (W.s/°C)	0.015			
C11 = C17 (W.s/°C)	0.05			
C12 = C18 (W.s/°C)	0.3			
C13 = C19 (W.s/°C)	1.2	2	2	2
C14 = C20 (W.s/°C)	2.5	3	4	5
C21 = C22 = C23 (W.s/°C)	0.01	0.008	0.008	0.008

1. The blank space means that the value is the same as the previous one.

4 Package and packing information

4.1 ECOPACK®

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: www.st.com. ECOPACK® is an ST trademark.

4.2 MultiPowerSO-30 mechanical data

Figure 23. MultiPowerSO-30 package dimensions

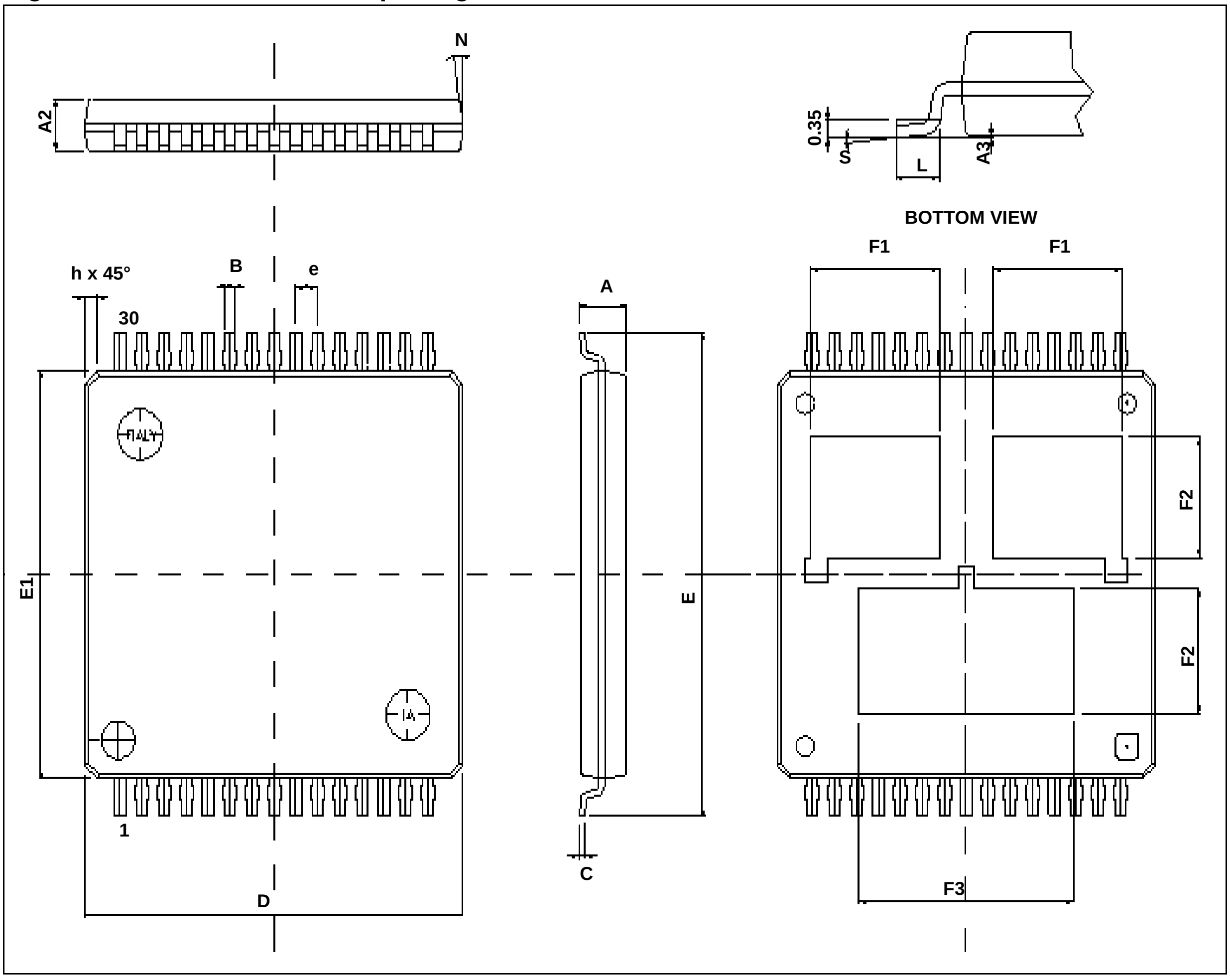
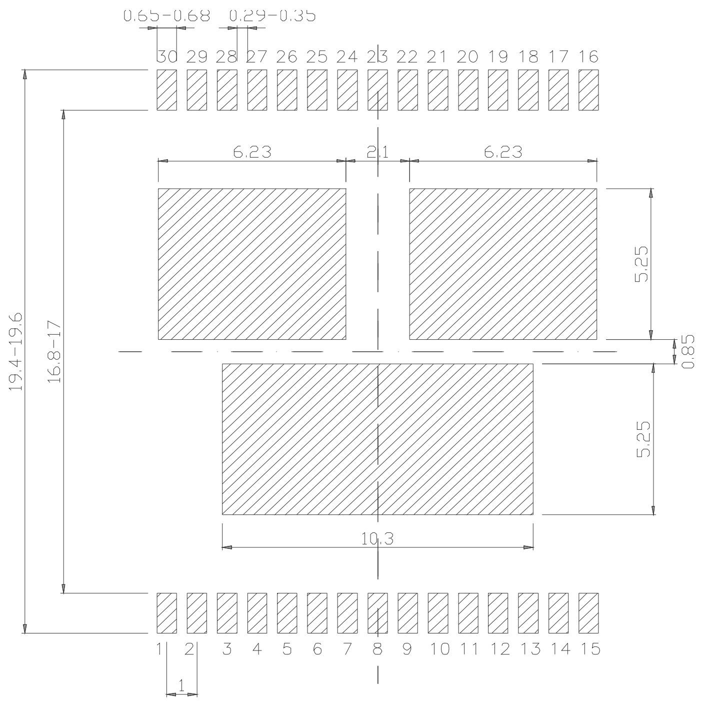


Table 19. MultiPowerSO-30 mechanical data

Symbol	Data book mm		
	Min.	Typ.	Max.
A			2.35
A2	1.85		2.25
A3	0		0.1
B	0.42		0.58
C	0.23		0.32
D	17.1	17.2	17.3
E	18.85		19.15
E1	15.9	16	16.1
e		1	
F1	5.55		6.05
F2	4.6		5.1
F3	9.6		10.1
L	0.8		1.15
N			10°
S	0°		7°

4.3 MultiPowerSO-30 suggested land pattern

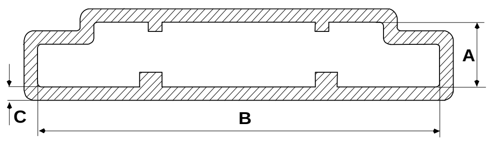
Figure 24. MultiPowerSO-30 suggested pad layout



4.4 MultiPowerSO-30 packing information

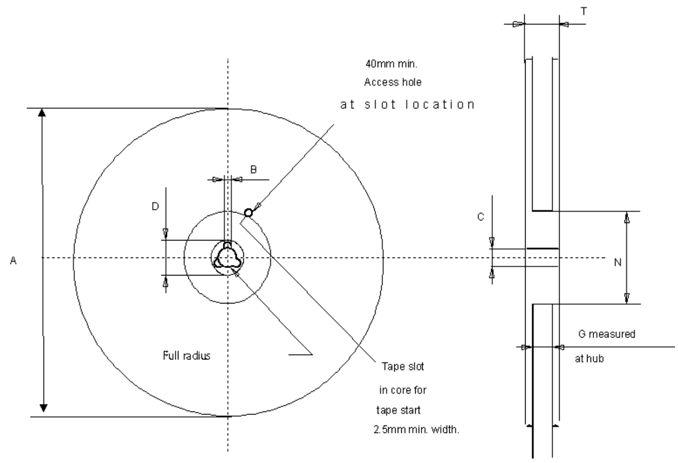
The devices can be packed in tube or tape and reel shipments (see *Table 20: Device summary* for packaging quantities).

Figure 25. MultiPowerSO-30 tube shipment (no suffix)



Dimension	mm
Base q.ty	29
Bulk q.ty	435
Tube length (± 0.5)	532
A	3.82
B	23.6
C (± 0.13)	0.8

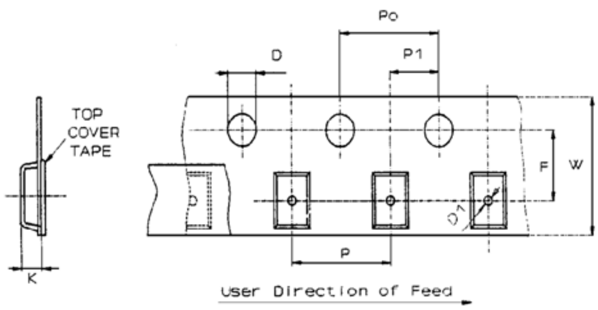
Figure 26. MultiPowerSO-30 tape and reel shipment (suffix “TR”)



Reel dimensions

SO-28 tube shipment (no suffix)

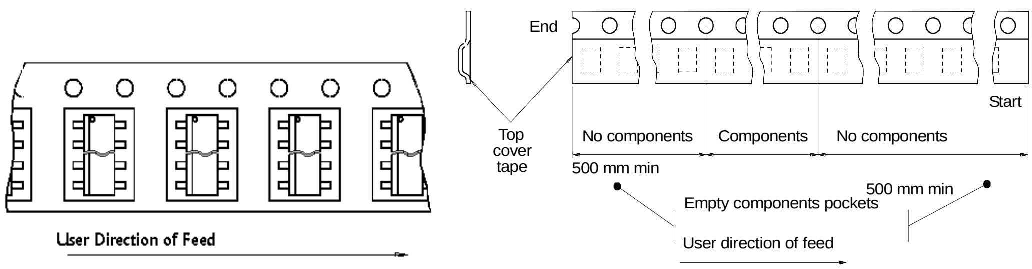
Dimension	mm
Base q.ty	1000
Bulk q.ty	1000
A (max)	330
B (min)	1.5
C (± 0.2)	13
D (min)	20.2
G (+ 2 / -0)	32
N (min)	100
T (max)	38.4



Tape dimensions

According to Electronic Industries Association (EIA) Standard 481 rev. A, Feb 1986

Description	Dimension	mm
Tape width	W	32
Tape hole spacing	P0 (± 0.1)	4
Component spacing	P	24
Hole diameter	D (± 0.1/-0)	1.5
Hole diameter	D1 (min)	2
Hole position	F (± 0.1)	14.2
Compartment Depth	K (max)	2.2
Hole Spacing	P1 (± 0.1)	2



5 Order codes

Table 20. Device summary

Package	Order codes	
	Tube	Tape and reel
MultiPowerSO-30	VNH5019A-E	VNH5019TR-E

6 Revision history

Table 21. Document revision history

Date	Revision	Changes
22-Jan-2008	1	Initial release.
04-Nov-2009	2	Uploaded corporate template by using V3 version Added *Table 5: Thermal data* *Section 2.1: Absolute maximum ratings* – Added text *Table 6: Power section* – I_S: added max value for $IN_A = IN_B = PWM = 0$; $T_j = 25$ °C; V_{CC}=13V in Test conditions, deleted $IN_A = IN_B = PWM = 0$ – V_f: changed Test conditions, changed typ/max value – I_{RM}: deleted and copied in *Table 8: Switching (V_{CC} = 13 V, R_{LOAD} = 0.87 W, Tj = 25 °C)* whole row *Table 8: Switching (V_{CC} = 13 V, R_{LOAD} = 0.87 W, Tj = 25 °C)* – t_{DEL}: changed min/typ/max value – Copied I_{RM} row by *Table 6: Power section* Updated *Table 10: Current sense (8 V < V_{CC} < 21 V)* *Table 11: Charge pump* – V_{CP}: changed min/max value for EN_X = 5 V, changed typ value for EN_X = 5 V, V_{CC} = 4.5 V Updated *Figure 11: Waveforms in full bridge operation (part 1)* Updated *Figure 12: Waveforms in full bridge operation (part 2)* Added *Chapter 4*
16-Dec-2009	3	Updated following tables: – *Table 6: Power section* – *Table 9: Protection and diagnostic* – *Table 10: Current sense (8 V < V_{CC} < 21 V)* Added *Figure 6: Behavior in fault condition (how a fault can be cleared)* Added *Chapter 3: Package and PCB thermal data*
06-Apr-2010	4	Updated *Table 5: Thermal data*. *Table 6: Power section*: – I_S: updated test condition and max value Updated table notes on *Table 9: Protection and diagnostic*. *Table 10: Current sense (8 V < V_{CC} < 21 V)*: – dK_0/k_0, dK_1/k_1, dK_3/k_3: updated minimum end maximum values.
19-Apr-2010	5	Updated *Table 10: Current sense (8 V < V_{CC} < 21 V)*.
25-May-2010	6	Updated *Features* list. Updated *Table 6: Power section*.
02-Sep-2010	7	Updated *Table 5: Thermal data*.

Table 21. Document revision history (continued)

Date	Revision	Changes
22-Dec-2011	8	Updated *Figure 1: Block diagram* Added *Table 1: Suggested connections for unused and not connected pins* Updated *Table 3: Block descriptions* *Table 8: Switching (V_{CC} = 13 V, R_{LOAD} = 0.87 W, Tj = 25 °C)*: – T_{TSD}, T_{TR}, T_{HYST}: added note – T_{TSD_LS}: added row Updated *Table 13: Truth table in fault conditions (detected on OUTA)* Updated *Figure 11: Waveforms in full bridge operation (part 1)* and *Figure 12: Waveforms in full bridge operation (part 2)*
19-Sep-2013	9	Updated Disclaimer.

McMASTER-CARR®

WINE OPENER P/N: B619

Glass-Tube Fuse

Time-Delay, 1/4" Diameter, Trade Size 3AG, 10A

1-9 Packs $9.29
10 or more $7.50
7085K15

Fuse Type	Glass
Protection Type	Time Delay
Manufacturer Equivalent	313, GDL, MDL
Fuse Trade Size	3AG
Current	10 A
Voltage	32V AC
Breakthrough Current	300 A @ 32 V AC
Overall Length	1 1/4"
Overall Diameter	1/4"
Number of Elements	1
Blown Fuse Indicator	Yes
Specifications Met	UL Recognized

Able to withstand current overload for a short time, these fuses will not open when exposed to harmless temporary surges. The clear glass tube makes it easy to see when fuses open. Use them with electronics, control panels, and other sensitive components. Select these fuses by their diameters. Designed for use with Fuse Blocks for Glass-Tube Fuses.

Breakthrough current, labeled on the fuse as IR, is the maximum current that a fuse can safely stop in the event of a short circuit.

McMASTER-CARR®

WINE OPENER P/N: B620

Inline Holder for Glass and Ceramic Tube Fuse

for 1/10-20A Fuse, 32V AC, Wire Lead Connection, 2.19" Long

$5.08 Each
7696K33

For Number of Fuses	1
For Fuse	
Manufacturer Equivalent	312, 313, 314, 322, 326, 505, ABC, AGC, GAB, GBB, GDL, GGC, GSA, MDA, MDL
Trade Size	3AB, 3AG
Current	1/10-20 A
Overall Diameter	1/4"
Overall Length	1 1/4"
Type	Ceramic, Glass
Voltage	32V AC
Wire Connection Type	Wire Lead
Mounting Location	Inline
Length	2.19"
Height	0.69"
Material	Plastic
RoHS	Not Compliant

Add fuse protection to a single wire.

Roll over image to zoom in

Lsgoodcare

Lsgoodcare 10Pack 5.5 x 2.5 MM 5A DC Power Jack Socket Threaded Female Mount Connector Adapter with Dustproof Plug

★★★★★ 3 customer reviews

Price: $12.99 ✓prime

FREE Shipping on orders over $25—or get **FREE Two-Day Shipping** with Amazon Prime

Promotion Available 1 Applicable Promotion

In Stock.

Want it Friday, June 1? Order within **14 hrs 24 mins** and choose **One-Day Shipping** at checkout. Details

Sold by Lsgoodcare and Fulfilled by Amazon. Gift-wrap available.

- 5A Dustproof DC Power Jack Socket Panel Mount Female Connector 5.5x2.5mm
- Materials : Metal;Main Color : Silver Tone
- Mount Hole Diameter : 11mm;Total Size : 16 x 17mm/0.63" x 0.67"(D*H)
- Connected to various power supplies for laptop computers, small televisions and other electronic;
- Package Content : 10 x DC Power Jack Socket + 10 x Dustproof Plug

New (2) from $12.99 & FREE shipping on orders over $25.00. Details

Product description

Lsgoodcare 10Pack 5.5 x 2.5 MM 5A DC Power Jack Socket Threaded Female Mount Connector Adapter with Dustproof Plug

The temperature range of use: - 30-70 ℃
The rated load: 5A DC30V
Contact resistance: ≤0.03Ω
Insulation resistance: ≥100MΩ
Withstand Voltage : AC 500V(50Hz)/min
Insertion and Extraction Force: 3N-20N
Life: 6000 times
Suitable for:
The av products: MP3, MP4, DVD. Audio;
Digital products: digital camera ect
The remote control: vehicles, ava door remote control, home security products;
Communication products: cell phones, car phone, telephone, building equipment, PDA, etc.
Household appliances, TV, microwave oven, electric cooker, electric wind, fat electronic body scale, electronic scale, electronic kitchen scale, etc.
Security products: video intercom, monitor, etc.;
Toys, electronic toys, etc.;
Computer products: cameras, voice recorder, etc.;
Fitness equipment: running machine, massage chairs, etc.;
Medical equipment: blood pressure, clinical thermometer, hospital call system, etc.

Note: when you solder the center pin, please keep the male plug connector inserted until the plastic has hardened, so that the insulator will not get too much heat to melt quickly.

Product information

Package Dimensions	4.8 x 3 x 0.5 inches
Item Weight	2.24 ounces
Shipping Weight	2.24 ounces (View shipping rates and policies)
Manufacturer	Lsgoodcare
ASIN	B072HK1DY4
Item model number	JACK-SR5A-2.5-5.5-10P
Customer Reviews	★★★★★ 3 customer reviews 5.0 out of 5 stars
Best Sellers Rank	#2,574 in Electronics > Accessories & Supplies > Audio & Video Accessories > Connectors & Adapters
Date first listed on Amazon	April 28, 2017

Feedback

If you are a seller for this product, would you like to **suggest updates through seller support**?
Would you like to **tell us about a lower price**?

WINE OPENER P/N: B622

Roll over image to zoom in

DROK

12V to 6V Converter, DROK Car Power Converter DC 9V-22V 12V to DC 6V Buck Voltage Regulator 3A 18W Waterproof High Efficiency Step Down Volt Module Power Supply

148 customer reviews | 23 answered questions

Was: ~~$11.47~~
Price: $9.99 prime
FREE Shipping on orders over $25—or get **FREE Two-Day Shipping** with Amazon Prime
You Save: $1.48 (13%)

Only 14 left in stock (more on the way).
Want it Friday, June 1? Order within **2 mins** and choose **Two-Day Shipping** at checkout. Details
Ships from and sold by Amazon.com. Gift-wrap available.

Size: **DC 12V to 6V**

DC 12V to 6V $9.99	DC 12V to 9V $6.77

- DROK car power converter input voltage range is DC 9V-22V, output voltage range is DC 6V, output current is 3A, output power is 18W.
- Module properties: synchronous rectification non-isolated buck module.
- Low Consumption: when it is no-load, the voltage reducer consumption is 10-12mA.
- Safe Protection: our voltage converter is designed with over-temperature and over-current protection, safe to use.
- Special Features: the volt transformer is Waterproof, Dust-proof, Shockproof, Suitable for all kinds of harsh environments.

Product description

Size:**DC 12V to 6V**

Specifications:
Module Properties: non-isolated buck module (BUCK)
Rectification: synchronous rectification
Input voltage: DC 12V (9-22V)
Output voltage: DC 6V
Output Current: 3A
Output Power: 18W
Lowest dropout:3V
Conversion efficiency: Max 95%
No-load consumption: 10-12mA
Working temperature: Industrial-grade (-40 °c to +85 °c)

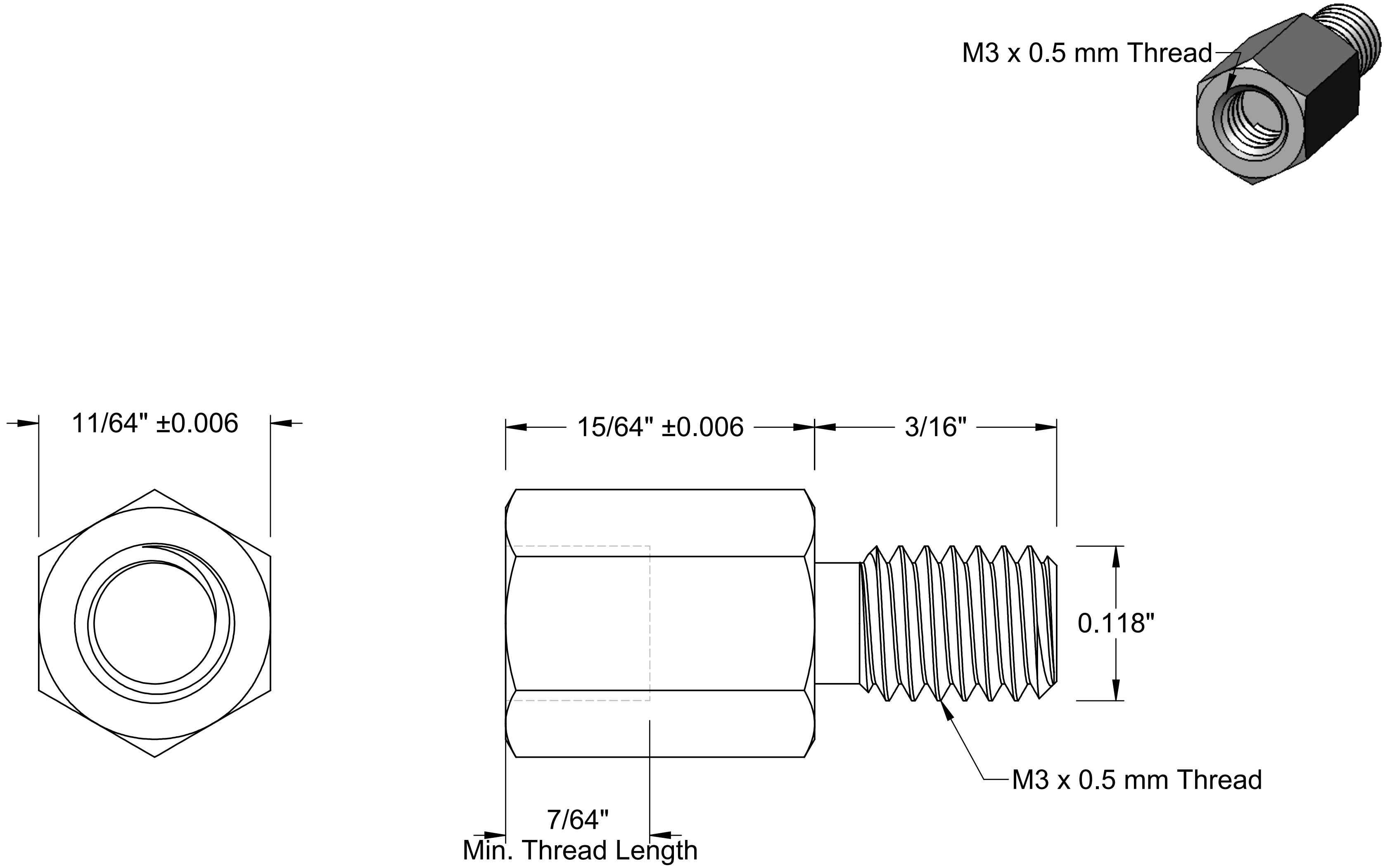
Features:
Overcurrent, overtemperature, short circuit protection
Waterproof, Dust-proof, Shockproof, Suitable for all kinds of harsh environments
Small size: 35x25.5x21mm (do not including install ear)

Package Includes:
1x DC/DC Converter

Product information

Size:**DC 12V to 6V**

Package Dimensions	3 x 1.9 x 1.2 inches
Item Weight	1.12 ounces
Shipping Weight	0.8 ounces (View shipping rates and policies)
Manufacturer	DROK
ASIN	B00CGQRIFG
Domestic Shipping	Currently, item can be shipped only within the U.S. and to APO/FPO addresses. For APO/FPO shipments, please check with the manufacturer regarding warranty and support issues.
International Shipping	This item can be shipped to select countries outside of the U.S. Learn More
Item model number	090597
Customer Reviews	148 customer reviews 4.6 out of 5 stars
Best Sellers Rank	#5,430 in Industrial & Scientific (See Top 100 in Industrial & Scientific) #219 in Automotive > Tools & Equipment > Garage & Shop > Power Converters
Date first listed on Amazon	April 22, 2013



WINE OPENER P/N: B627

McMASTER-CARR® CAD	PART NUMBER	95783A053
http://www.mcmaster.com © 2016 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Male-Female Threaded Hex Standoff	

General Specifications

Electrical Capacity (Resistive Load)

Power Level (silver):	6A @ 125V AC or 3A @ 250V AC or 3A @ 30V DC
Logic Level (gold):	0.4VA maximum @ 28V AC/DC maximum (Applicable Range 0.1mA ~ 0.1A @ 20mV ~ 28V) Note: Find additional explanation of operating range in Supplement section.

Other Ratings

Contact Resistance:	10 milliohms maximum for silver; 20 milliohms maximum for gold
Insulation Resistance:	1,000 megohms minimum @ 500V DC
Dielectric Strength:	1,000V AC minimum between contacts for 1 minute minimum; 1,500V AC minimum between contacts & case for 1 minute minimum
Mechanical Life:	50,000 operations minimum
Electrical Life:	25,000 operations minimum

Nominal Operating Force:

	On-to-On Position	Off-to-On Position
Single Pole	3.19N	3.92N
Double Pole	4.41N	7.06N

Angle of Throw: 20°

Materials & Finishes

Bushing:	Brass with nickel plating
Housing:	Stainless steel
Mounting Bracket:	Steel with tin plating
Movable Contacts:	Silver alloy or silver alloy with gold plating
Stationary Contacts:	Silver with silver plating or copper or brass with gold plating
Lamp Contacts:	Phosphor bronze
Base:	Diallyl phthalate (UL94V-0)
Switch Terminals:	Copper with silver or gold plating
Lamp Terminals:	Brass with silver or gold plating

Environmental Data

Operating Temp Range:	–10°C through +55°C (+14°F through +131°F)
Humidity:	90 ~ 95% humidity for 96 hours @ 40°C (104°F)
Vibration:	10 ~ 55Hz with peak-to-peak amplitude of 1.5mm traversing the frequency range & returning in 1 minute; 3 right angled directions for 2 hours
Shock:	50G (490m/s²) acceleration (tested in 6 right angled directions, with 5 shocks in each direction)

Installation

Mounting Torque:	1.47Nm (13 lb•in) for double nut; .67Nm (6 lb•in) for single nut
Soldering Time & Temp:	Wave Soldering (PC version): See Profile B in Supplement section. Manual Soldering: See Profile B in Supplement section. Note: Lever must be in center position while soldering.
Cleaning:	PC mountable device is not process sealed. Hand clean locally using alcohol based solution.

Standards & Certifications

Flammability Standards:	UL94V-0 base
UL:	**File No. E44145 - Recognized only when ordered with marking on switch.** Add "/U" to end of part number to order UL recognized switch. Single pole with synchronous circuits & single color LEDs & solder lug or PC recognized at 6A @ 125V AC.
CSA:	**File No. 023535_0_000 - Certified only when ordered with marking on switch.** Add "/C" to end of part number to order CSA certified switch. All single pole with synchronous circuits & single color LEDs certified at 6A @ 125V AC.

Distinctive Characteristics

Industry's first LED illumination at tip of toggle switches.

Single color LEDs of red, yellow, and green, plus bicolor red/green, to meet varied design requirements.

LEDs can operate independently from or synchronously with switching operation.

Antijamming feature to protect contacts from damage due to excessive downward force on the toggle.

High torque bushing prevents the bushing from rotating or separating from the metal frame during installation.

Stainless steel frame resists corrosion.

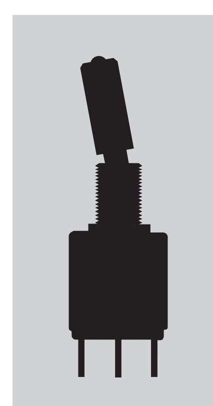
Silver contacts are of specially composed alloy for hardness.

High insulating barriers protect against crossover in double pole devices.

Terminals are molded in and epoxy sealed to lock out flux, dust, and other contaminants.

1,500V dielectric strength between switch contacts and case is accomplished by clinching the frame away from the terminals.

Actual Size



TYPICAL SWITCH ORDERING EXAMPLE

M21 | 1 | 2 | T | C | W | 01 |

Poles

1	SPDT
* 2	DPDT

* Available only with Terminals 01, 02, 03

LED Circuits & Actuator Types

L	Isolated
T	Synchronous

Contact Materials & Ratings

W	Silver; Rated 6A @ 125V AC
G	Gold; Rated 0.4VA max @ 28V AC/DC max

Threaded Bushings

No Code	1/4–40 Thread (Inch)
/M	6mm Thread (Metric)

Circuits

2	ON	NONE	ON
3	ON	OFF	ON

LED Colors

Single Color	
C	Red
E	Yellow
F	Green
Bicolor	
CF	Red/Green

Terminals & Mounting Types

01	Solder Lug with Threaded Bushing
02	Quick Connect with Threaded Bushing
03	Straight PC with Threaded Bushing
30	Right Angle PC with Smooth Bushing (available with gold contacts only)

IMPORTANT:

Switches are supplied without UL & CSA marking unless specified.
UL & CSA recognized only when ordered with marking on the switch.
Specific models, ratings, & ordering instructions are noted on the General Specifications page.

DESCRIPTION FOR TYPICAL ORDERING EXAMPLE

M2112TCW01

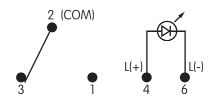
POLES & CIRCUITS & LED ILLUMINATION

Model		Pole & Throw	Toggle Position & Terminal Numbers: Down	Center	Up
					
M2112 Connected Power Terminals		**SPDT**	ON 2-3	NONE NONE	ON 2-1
LED Circuit	**Isolated LEDs** (see schematics) Connected LED Terminals		ON 4-6	NONE NONE	ON 4-6
LED Circuit	**Synchronous Single Color LED** Connected LED Terminals		ON 4-6	NONE NONE	OFF OPEN
LED Circuit	**Synchronous Bicolor LED** Connected LED Terminals		Red 5-6	NONE NONE	Green 5-4
M2113 Connected Power Terminals		**SPDT**	ON 2-3	OFF OPEN	ON 2-1
LED Circuit	**Isolated LEDs** (see schematics) Connected LED Terminals		ON 4-6	ON 4-6	ON 4-6
LED Circuit	**Synchronous Single Color LED** Connected LED Terminals		ON 4-6	OFF OPEN	ON 4-6
LED Circuit	**Synchronous Bicolor LED** Connected LED Terminals		Red 5-6	OFF OPEN	Green 5-4
M2122 Connected Power Terminals		**DPDT**	ON 2-3 5-6	NONE NONE	ON 2-1 5-4
LED Circuit	**Isolated LEDs** (see schematics) Connected LED Terminals		ON 7-9	NONE NONE	ON 7-9
LED Circuit	**Synchronous Single Color LED** Connected LED Terminals		ON 7-9	NONE NONE	OFF OPEN
LED Circuit	**Synchronous Bicolor LED** Connected LED Terminals		Red 8-9	NONE NONE	Green 8-7
M2123 Connected Power Terminals		**DPDT**	ON 2-3 5-6	OFF OPEN	ON 2-1 5-4
LED Circuit	**Isolated LEDs** (see schematics) Connected LED Terminals		ON 7-9	ON 7-9	ON 7-9
LED Circuit	**Synchronous Single Color LED** Connected LED Terminals		ON 7-9	OFF OPEN	ON 7-9
LED Circuit	**Synchronous Bicolor LED** Connected LED Terminals		Red 8-9	OFF OPEN	Green 8-7

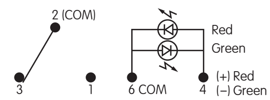
Schematics

Notes: Terminal numbers are not actually on the switch.
LEDs require an external power source.

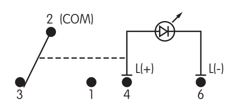
Isolated Single Color LED



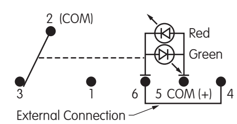
Isolated Bicolor LED



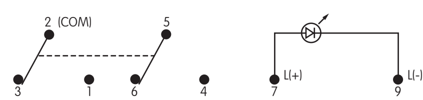
Synchronous Single Color LED



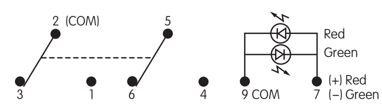
Synchronous Bicolor LED



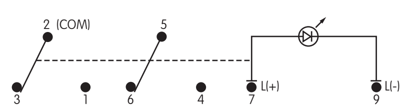
Isolated Single Color LED



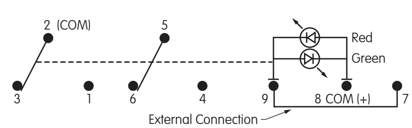
Isolated Bicolor LED



Synchronous Single Color LED



Synchronous Bicolor LED



LED COLORS & SPECIFICATIONS

The electrical specifications shown are determined at a basic temperature of 25°C. LED circuit is isolated and requires an external power source. If the source voltage exceeds the rated voltage, a ballast resistor is required. The resistor value can be calculated by using the formula in Supplement Section.

The LED is an integral part of the switch and not available separately. Bicolor LED is translucent white when unlit.		Single Color			Bicolor	
		C	E	F	CF	
	Color	Red	Yellow	Green	Red/Green	Units
Maximum Forward Current	I_{FM}	30	30	30	25	mA
Typical Forward Current	I_F	20	20	20	10	mA
Forward Voltage	V_F	2.2	2.1	2.2	1.7/2.0	V
Maximum Reverse Voltage	V_{RM}	4	4	4	—	V
Current Reduction Rate Above 25°C	ΔI_F	0.38	0.38	0.38	0.33/0.33	mA/°C
Ambient Temperature Range		−10° ~ +55°C				

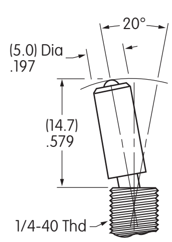
LED CIRCUIT, TOGGLE, & MOUNTING TYPE COMBINATIONS

L **Toggle with Isolated LED Circuit**

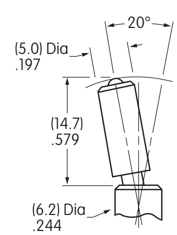
T **Toggle with Synchronous LED Circuit**

Finish: Brushed aluminum

Standard Hardware: 2 AT513H Hex Nuts, 1 AT507H Locking Ring, 1 AT509 Lockwasher Standard & optional hardware details in Accessories & Hardware section.

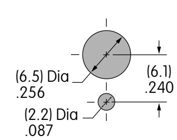


Threaded Bushing combines with Terminal codes 01, 02, & 03.

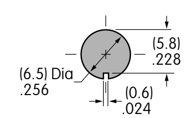


Smooth Bushing combines with Terminal code 30.

Max. Panel Thickness with Standard Hardware .102" (2.6mm)



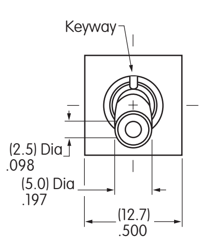
Max. Panel Thickness without Locking Ring .134" (3.4mm)



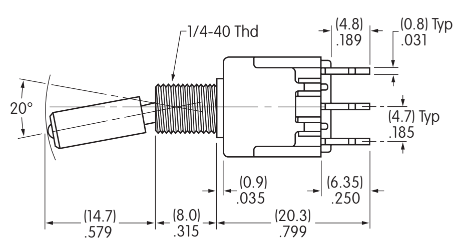
TYPICAL SWITCH DIMENSIONS

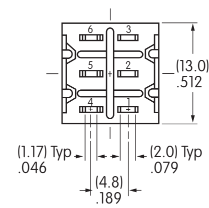
Solder Lug

M2112TCFW01



Single Pole



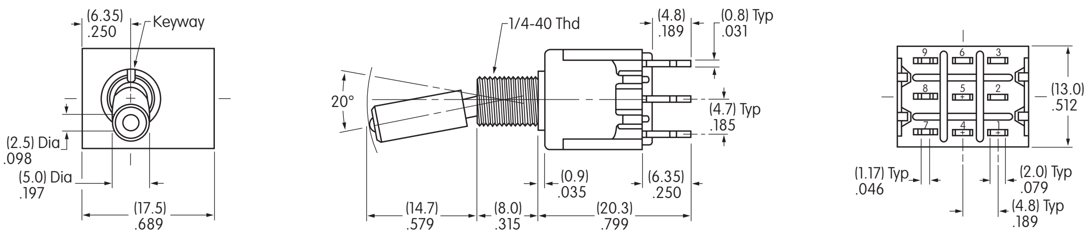


Single color LED switch does not have terminal 5.

TYPICAL SWITCH DIMENSIONS

Double Pole

Solder Lug

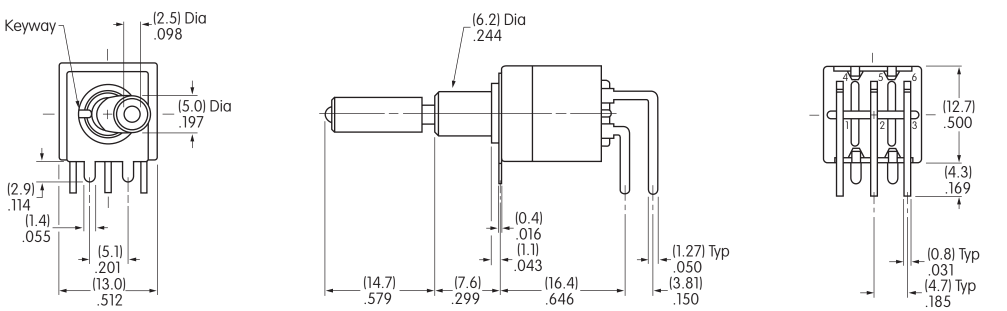


Single color LED switch does not have terminal 8.

M2122TCFW01

Single Pole Only

Right Angle PC



Single color LED switch does not have terminal 5.

Gold contact material only

M2112TCFG30

CONTACT MATERIALS & RATINGS

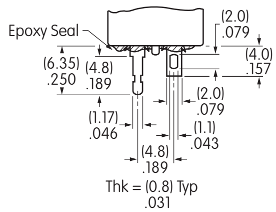
W	**Silver over Silver**	**Power Level**	**6A @ 125V AC & 3A @ 250V AC**
G	**Gold over Brass or Copper**	**Logic Level**	**0.4VA maximum @ 28V AC/DC maximum**

Complete explanation of operating range in Supplement section.

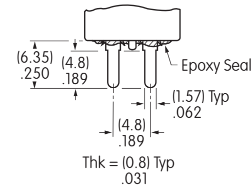
Toggles A
Rockers
Pushbuttons
Illuminated PB
Programmable
Keylocks
Rotaries
Slides
Tactiles
Tilt
Touch
Indicators
Accessories
Supplement

TERMINALS

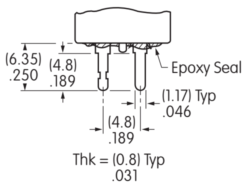
01 **Solder Lug with Turret LED Terminal**



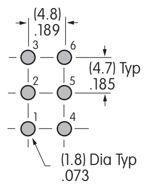
02 **Quick Connect**



03 **Straight PC with Turret LED Terminal**

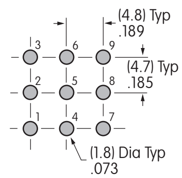


Single Pole



Single color LED & isolated bicolor LED switches do not have terminal 5.

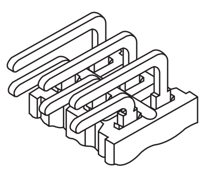
Double Pole



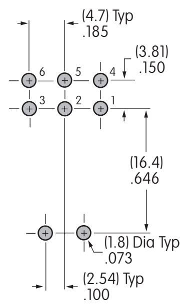
Single color LED & isolated bicolor LED switches do not have terminal 8.

30 **Right Angle PC**

LED terminals only available in brass with silver plating



Single Pole

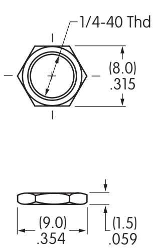


Single color LED & isolated bicolor LED switches do not have terminal 5.

STANDARD MOUNTING HARDWARE

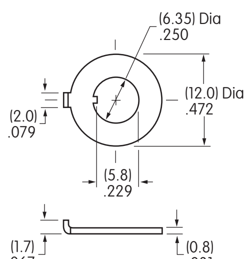
AT513H Hexagon Nut
(2 per switch)

Material:
Brass with nickel plating



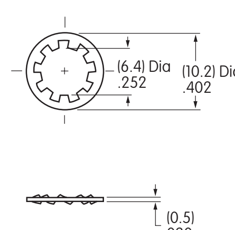
AT507H Locking Ring
(1 per switch)

Material:
Steel with chromate over zinc



AT509 Lockwasher
(1 per switch)

Material:
Steel with chromate over zinc



Optional Hardware: Knurled nuts, dress nuts, and ON-OFF plates are available; see details in Accessories & Hardware section.

Mouser Electronics

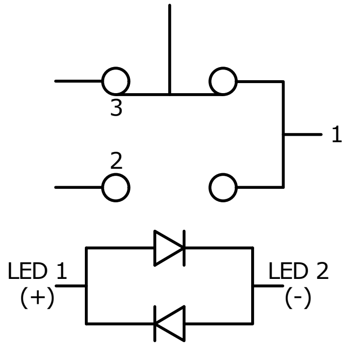
Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

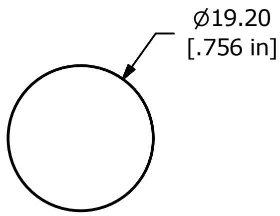
NKK Switches:

M2113LFW03 M2112LCFG01 M2112LFW03 M2113TCW01 M2112TEW01 M2123TCFW01 M2113TCFW01 M2123LFG01 M2123TFG02 M2113TCFG02 M2123TCFW02 M2112LCFW03 M2123LCFG01 M2112LEW02 M2113LFW02 M2112JCFG01-A M2113PCFG02-A M2113REG02 M2112PCW01-A M2112JCFW01-G M2112JCW01-A M2112JCFW01-A M2113RCFW02 M2112JFW02-H M2112PFW01-A M2113JFW01-A M2113PCG01-A M2112PCW01-C M2112JCFG03-A M2113PCG01-H M2113JCG01-H M2123LCFW03 M2113PCW02-A M2112LCFW01-RO M2113RCW01 M2113NCFG03 M2113NCFG13 M2122NCFW01 M2123LCFW01 M2112LCG01 M2122TCG01 M2122TEG01 M2112TCFG01 M2123LEW02 M2123LFW02 M2123LCFW02 M2123TFW03 M2123TCFW03 M2113TCG03 M2112LCFG03 M2113LCFG03 M2123LCFG03 M2112NCFG30 M2112PCFG13 M2113PCFG13 M2113TEFW01-RO M2113JFG02-A M2112JFW01-H M2113PCW01A M2112TCFW13 M2123TCFW13 M2113PFW01-F M2112TCFW01/CUL M2113TFW01/CUL M2112NCFG01 M2112TCW01/CUL M2112TFW01/CUL M2112RFG01 M2113TEW01 M2113PCW13 M2113JEW13 M2113PCG01 M2112JEW13 M2113JCFW13 M2112PEW01-A M2113NCFW01 M2113JCW13 M2112JFW01-F M2113PFW01-A M2112REW01 M2112PCW01-G M2113JCW01 M2112JEW01-G M2123NCFW01 M2112NEW01 M2112RCW01 M2113NCW01 M2112PCW01 M2112RCFW01 M2113PFW01 M2122RCG03 M2113RCW13 M2112JEW01 M2113JFW01 M2112PEW01 M2113JEW01 M2113JCFW01-H M2122RFW03 M2113JFW01-H M2113NCW13

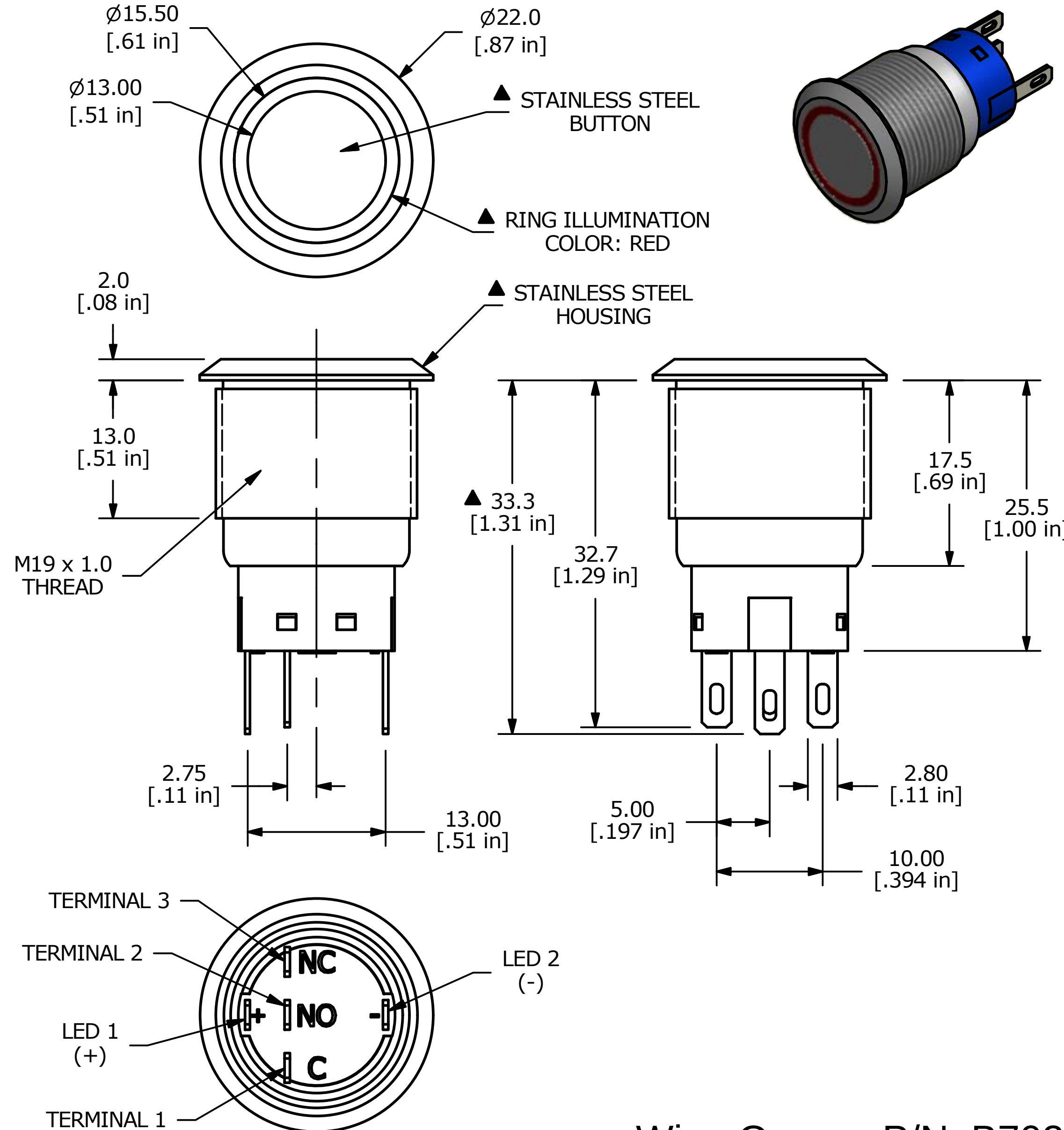
SHEET 1 OF 1



▲ SCHEMATIC
ON - ON
SPDT Illuminated



PANEL CUT-OUT
PANEL THICKNESS 1-10mm



NOTE:
1. ALL DIMENSIONS IN MM [INCH]
2. GENERAL TOLERANCE: X.X = ±0.4
X.XX = ±0.25
3. TERMINAL NUMBERS FOR REF ONLY
▲ 4. CONTACT MATERIAL: SILVER
5. RATING: 3A 250 VAC cUL
6. ELECTRIC LIFE: 50,000 MAKE-AND-BREAK CYCLES AT FULL LOAD.
7. MECHANICAL LIFE: 500,000 CYCLES
8. INSULATION RESISTANCE: 1,000 MΩ @ 500VDC MIN.
9. DIELECTRIC STRENGTH: 2,000 VAC MIN. FOR 1 MINUTE
10. CONTACT RESISTANCE: 50mΩ MAX. @ 1A 12VDC
11. OPERATING TEMP.: -20°C to 55°C
12. ▲ DENOTES CRITICAL PARAMETER.
▲ 13. LAMP VOLTAGE: 20mA 3V
14. TRAVEL: 3.2mm
15. ACTUATION FORCE: 2.5 ± 1.0 N
16 MOUNTING NUT TORQUE: 5-14 Nm
17. INGRESS PROTECTION: IP67
18. HARDWARE SUPPLIED: O-RING AND HEXNUT

Wine Opener P/N: B702

REV	PCR NO	DESCRIPTION	DATE	BY
C	22216	Update inside Ring diameter to 13.00mm	3/23/16	MW
B	22127	UPDATE HOUSING DIM. TO 1 PLACE DECIMAL	1/19/16	MW
A	21865	New Release	6/2/15	rc

E-SWITCH®

TITLE ULV4F23SS311

SCALE	DATE	DR	DWG	REV
1.5 : 1	5/29/2015	rc	00	C

SONGLE RELAY

松乐继电器 ® SONGLE RELAY	RELAY ISO9002	**SRD**

1. MAIN FEATURES

- Switching capacity available by 10A in spite of small size design for highdensity P.C. board mounting technique.
- UL,CUL,TUV recognized.
- Selection of plastic material for high temperature and better chemical solution performance.
- Sealed types available.
- Simple relay magnetic circuit to meet low cost of mass production.

2. APPLICATIONS

- Domestic appliance, office machine, audio, equipment, automobile, etc.
  (Remote control TV receiver, monitor display, audio equipment high rushing current use application.)

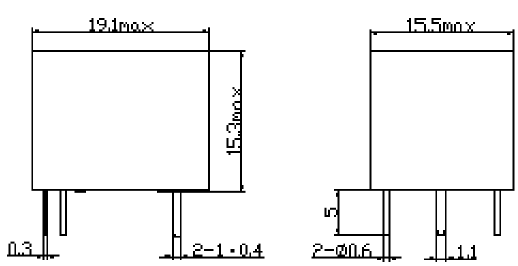
3. ORDERING INFORMATION

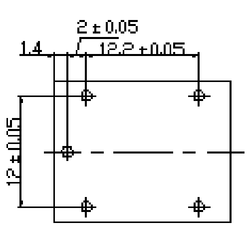
SRD	XX VDC	S	L	C
Model of relay	Nominal coil voltage	Structure	Coil sensitivity	Contact form
SRD	03、05、06、09、12、24、48VDC	S:Sealed type	L:0.36W	A:1 form A
				B:1 form B
		F:Flux free type	D:0.45W	C:1 form C

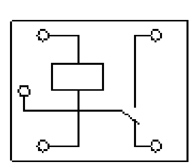
4. RATING

CCC	FILE NUMBER:CH0052885-2000	7A/240VDC
CCC	FILE NUMBER:CH0036746-99	10A/250VDC
UL /CUL	FILE NUMBER: E167996	10A/125VAC 28VDC
TUV	FILE NUMBER: R9933789	10A/240VAC 28VDC

5. DIMENSION(unit:mm) DRILLING(unit:mm) WIRING DIAGRAM







6. COIL DATA CHART (AT20°C)

Coil Sensitivity	Coil Voltage Code	Nominal Voltage (VDC)	Nominal Current (mA)	Coil Resistance (Ω) ±10%	Power Consumption (W)	Pull-In Voltage (VDC)	Drop-Out Voltage (VDC)	Max-Allowable Voltage (VDC)
SRD (High Sensitivity)	03	03	120	25	abt. 0.36W	75%Max.	10% Min.	120%
	05	05	71.4	70				
	06	06	60	100				
	09	09	40	225				
	12	12	30	400				
	24	24	15	1600				
	48	48	7.5	6400				
SRD (Standard)	03	03	150	20	abt. 0.45W	75% Max.	10% Min.	110%
	05	05	89.3	55				
	06	06	75	80				
	09	09	50	180				
	12	12	37.5	320				
	24	24	18.7	1280				
	48	48	10	4500	abt. 0.51W			

7. CONTACT RATING

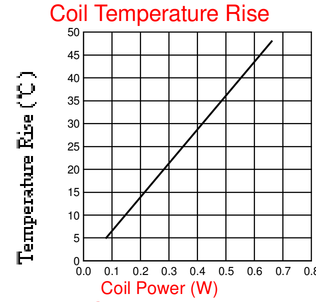
Type / Item	SRD FORM C	SRD FORM A
Contact Capacity Resistive Load (cosΦ=1)	7A 28VDC 10A 125VAC 7A 240VAC	10A 28VDC 10A 240VAC
Inductive Load (cosΦ=0.4 L/R=7msec)	3A 120VAC 3A 28VDC	5A 120VAC 5A 28VDC
Max. Allowable Voltage	250VAC/110VDC	250VAC/110VDC
Max. Allowable Power Force	800VAC/240W	1200VA/300W
Contact Material	AgCdO	AgCdO

8. PERFORMANCE (at initial value)

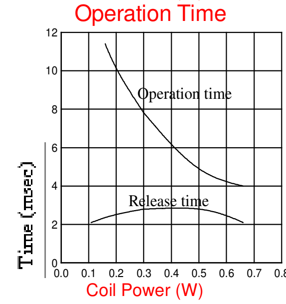
Type / Item	SRD
Contact Resistance	100mΩ Max.
Operation Time	10msec Max.
Release Time	5msec Max.
Dielectric Strength Between coil & contact Between contacts	 1500VAC 50/60HZ (1 minute) 1000VAC 50/60HZ (1 minute)
Insulation Resistance	100 MΩ Min. (500VDC)
Max. ON/OFF Switching Mechanically Electrically	 300 operation/min 30 operation/min
Ambient Temperature	-25°C to +70°C
Operating Humidity	45 to 85% RH
Vibration Endurance Error Operation	 10 to 55Hz Double Amplitude 1.5mm 10 to 55Hz Double Amplitude 1.5mm
Shock Endurance Error Operation	 100G Min. 10G Min.
Life Expectancy Mechanically Electrically	 10^7 operations. Min. (no load) 10^5 operations. Min. (at rated coil voltage)
Weight	abt. 10grs.

9.REFERENCE DATA

Coil Temperature Rise

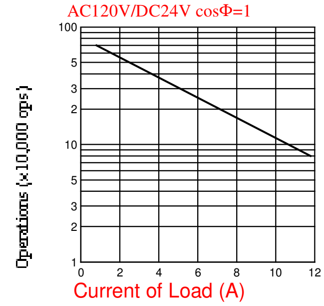


Operation Time

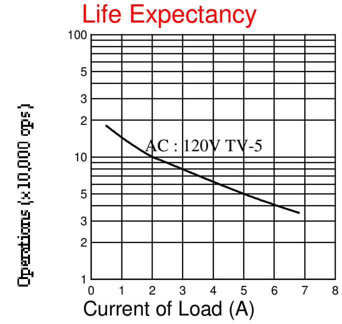


Life Expectancy

AC120V/DC24V cosΦ=1

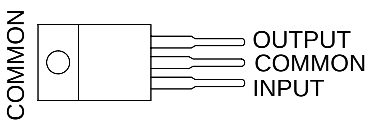


Life Expectancy

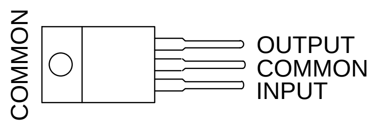


- **3-Terminal Regulators**
- **Output Current up to 1.5 A**
- **Internal Thermal-Overload Protection**
- **High Power-Dissipation Capability**
- **Internal Short-Circuit Current Limiting**
- **Output Transistor Safe-Area Compensation**

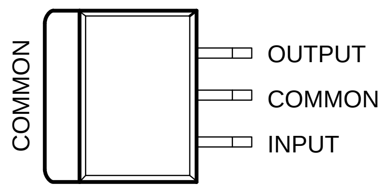
KC (TO-220) PACKAGE
(TOP VIEW)



KCS (TO-220) PACKAGE
(TOP VIEW)



KTE PACKAGE
(TOP VIEW)



description/ordering information

This series of fixed-voltage integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 A of output current. The internal current-limiting and thermal-shutdown features of these regulators essentially make them immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents, and also can be used as the power-pass element in precision regulators.

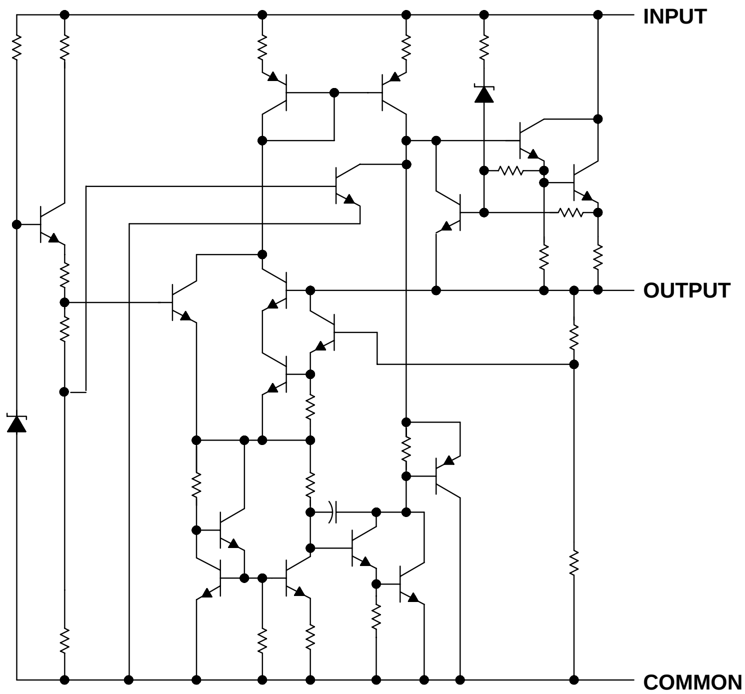
ORDERING INFORMATION

T_J	$V_{O(NOM)}$ (V)	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 125°C	5	POWER-FLEX (KTE)	Reel of 2000	µA7805CKTER	µA7805C
		TO-220 (KC)	Tube of 50	µA7805CKC	µA7805C
		TO-220, short shoulder (KCS)	Tube of 20	µA7805CKCS	
	8	POWER-FLEX (KTE)	Reel of 2000	µA7808CKTER	µA7808C
		TO-220 (KC)	Tube of 50	µA7808CKC	µA7808C
		TO-220, short shoulder (KCS)	Tube of 20	µA7808CKCS	
	10	POWER-FLEX (KTE)	Reel of 2000	µA7810CKTER	µA7810C
		TO-220 (KC)	Tube of 50	µA7810CKC	µA7810C
	12	POWER-FLEX (KTE)	Reel of 2000	µA7812CKTER	µA7812C
		TO-220 (KC)	Tube of 50	µA7812CKC	µA7812C
		TO-220, short shoulder (KCS)	Tube of 20	µA7812CKCS	
	15	POWER-FLEX (KTE)	Reel of 2000	µA7815CKTER	µA7815C
		TO-220 (KC)	Tube of 50	µA7815CKC	µA7815C
		TO-220, short shoulder (KCS)	Tube of 20	µA7815CKCS	
	24	POWER-FLEX (KTE)	Reel of 2000	µA7824CKTER	µA7824C
		TO-220 (KC)	Tube of 50	µA7824CKC	µA7824C

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

schematic



absolute maximum ratings over virtual junction temperature range (unless otherwise noted)†

Input voltage, V_I: μA7824C . . . . 40 V
All others . . . . 35 V
Operating virtual junction temperature, T_J . . . . 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C
Storage temperature range, T_{stg} . . . . –65°C to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

package thermal data (see Note 1)

PACKAGE	BOARD	θ_{JC}	θ_{JA}
POWER-FLEX (KTE)	High K, JESD 51-5	3°C/W	23°C/W
TO-220 (KC/KCS)	High K, JESD 51-5	3°C/W	19°C/W

NOTE 1: Maximum power dissipation is a function of T_J(max), θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.

recommended operating conditions

			MIN	MAX	UNIT
V_I	Input voltage	μA7805C	7	25	V
		μA7808C	10.5	25	
		μA7810C	12.5	28	
		μA7812C	14.5	30	
		μA7815C	17.5	30	
		μA7824C	27	38	
I_O	Output current			1.5	A
T_J	Operating virtual junction temperature	μA7800C series	0	125	°C

electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	μA7805C			UNIT
			MIN	TYP	MAX	
Output voltage	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, $P_D \le$ 15 W	25°C	4.8	5	5.2	V
		0°C to 125°C	4.75		5.25	
Input voltage regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to 125°C	62	78		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		μV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

electrical characteristics at specified virtual junction temperature, V_I = 14 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	µA7808C MIN	µA7808C TYP	µA7808C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 10.5 V to 23 V, P_D ≤ 15 W	25°C	7.7	8	8.3	V
		0°C to 125°C	7.6		8.4	
Input voltage regulation	V_I = 10.5 V to 25 V	25°C		6	160	mV
	V_I = 11 V to 17 V			2	80	
Ripple rejection	V_I = 11.5 V to 21.5 V, f = 120 Hz	0°C to 125°C	55	72		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		12	160	mV
	I_O = 250 mA to 750 mA			4	80	
Output resistance	f = 1 kHz	0°C to 125°C		0.016		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–0.8		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		52		µV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 10.5 V to 25 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		450		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

electrical characteristics at specified virtual junction temperature, V_I = 17 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	µA7810C MIN	µA7810C TYP	µA7810C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 12.5 V to 25 V, P_D ≤ 15 W	25°C	9.6	10	10.4	V
		0°C to 125°C	9.5	10	10.5	
Input voltage regulation	V_I = 12.5 V to 28 V	25°C		7	200	mV
	V_I = 14 V to 20 V			2	100	
Ripple rejection	V_I = 13 V to 23 V, f = 120 Hz	0°C to 125°C	55	71		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		12	200	mV
	I_O = 250 mA to 750 mA			4	100	
Output resistance	f = 1 kHz	0°C to 125°C		0.018		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		70		µV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 12.5 V to 28 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		400		mA
Peak output current		25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-µF capacitor across the input and a 0.1-µF capacitor across the output.

electrical characteristics at specified virtual junction temperature, V_I = 19 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS		T_J†	μA7812C MIN	μA7812C TYP	μA7812C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, $P_D \leq$ 15 W	V_I = 14.5 V to 27 V,	25°C	11.5	12	12.5	V
			0°C to 125°C	11.4		12.6	
Input voltage regulation	V_I = 14.5 V to 30 V		25°C		10	240	mV
	V_I = 16 V to 22 V				3	120	
Ripple rejection	V_I = 15 V to 25 V,	f = 120 Hz	0°C to 125°C	55	71		dB
Output voltage regulation	I_O = 5 mA to 1.5 A		25°C		12	240	mV
	I_O = 250 mA to 750 mA				4	120	
Output resistance	f = 1 kHz		0°C to 125°C		0.018		Ω
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		–1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		75		μV
Dropout voltage	I_O = 1 A		25°C		2		V
Bias current			25°C		4.3	8	mA
Bias current change	V_I = 14.5 V to 30 V		0°C to 125°C			1	mA
	I_O = 5 mA to 1 A					0.5	
Short-circuit output current			25°C		350		mA
Peak output current			25°C		2.2		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

electrical characteristics at specified virtual junction temperature, V_I = 23 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS		T_J†	μA7815C MIN	μA7815C TYP	μA7815C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, $P_D \leq$ 15 W	V_I = 17.5 V to 30 V,	25°C	14.4	15	15.6	V
			0°C to 125°C	14.25		15.75	
Input voltage regulation	V_I = 17.5 V to 30 V		25°C		11	300	mV
	V_I = 20 V to 26 V				3	150	
Ripple rejection	V_I = 18.5 V to 28.5 V,	f = 120 Hz	0°C to 125°C	54	70		dB
Output voltage regulation	I_O = 5 mA to 1.5 A		25°C		12	300	mV
	I_O = 250 mA to 750 mA				4	150	
Output resistance	f = 1 kHz		0°C to 125°C		0.019		Ω
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		–1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		90		μV
Dropout voltage	I_O = 1 A		25°C		2		V
Bias current			25°C		4.4	8	mA
Bias current change	V_I = 17.5 V to 30 V		0°C to 125°C			1	mA
	I_O = 5 mA to 1 A					0.5	
Short-circuit output current			25°C		230		mA
Peak output current			25°C		2.1		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

electrical characteristics at specified virtual junction temperature, V_I = 33 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	T_J†	μA7824C MIN	μA7824C TYP	μA7824C MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, V_I = 27 V to 38 V, P_D ≤ 15 W	25°C	23	24	25	V
		0°C to 125°C	22.8		25.2	
Input voltage regulation	V_I = 27 V to 38 V	25°C		18	480	mV
	V_I = 30 V to 36 V			6	240	
Ripple rejection	V_I = 28 V to 38 V, f = 120 Hz	0°C to 125°C	50	66		dB
Output voltage regulation	I_O = 5 mA to 1.5 A	25°C		12	480	mV
	I_O = 250 mA to 750 mA			4	240	
Output resistance	f = 1 kHz	0°C to 125°C		0.028		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		–1.5		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		170		μV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		4.6	8	mA
Bias current change	V_I = 27 V to 38 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		150		mA
Peak output current		25°C		2.1		A

† Pulse-testing techniques maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

APPLICATION INFORMATION

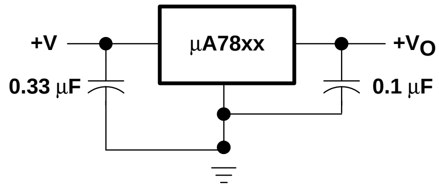


Figure 1. Fixed-Output Regulator

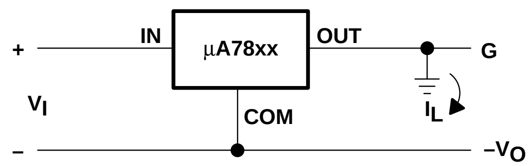
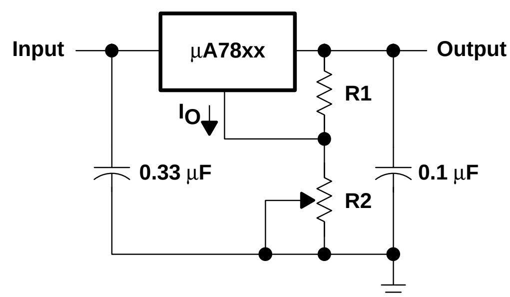


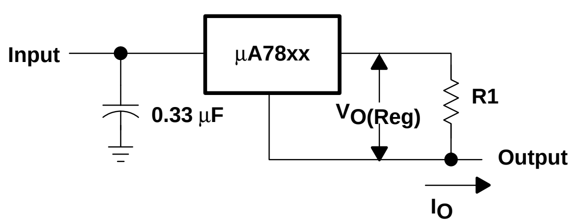
Figure 2. Positive Regulator in Negative Configuration (V_I Must Float)



NOTE A: The following formula is used when V_{XX} is the nominal output voltage (output to common) of the fixed regulator:

$$V_O = V_{xx} + \left(\frac{V_{xx}}{R1} + I_Q\right)R2$$

Figure 3. Adjustable-Output Regulator



$I_O = (V_O/R1) + I_O$ Bias Current

Figure 4. Current Regulator

APPLICATION INFORMATION

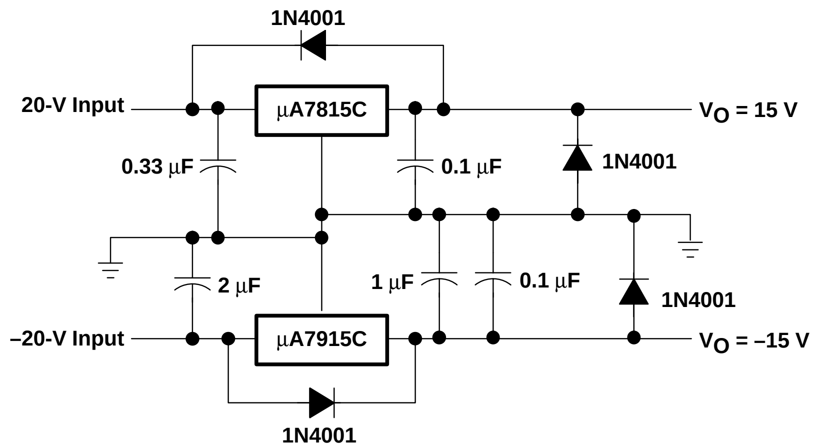


Figure 5. Regulated Dual Supply

operation with a load common to a voltage of opposite polarity

In many cases, a regulator powers a load that is not connected to ground but, instead, is connected to a voltage source of opposite polarity (e.g., operational amplifiers, level-shifting circuits, etc.). In these cases, a clamp diode should be connected to the regulator output as shown in Figure 6. This protects the regulator from output polarity reversals during startup and short-circuit operation.

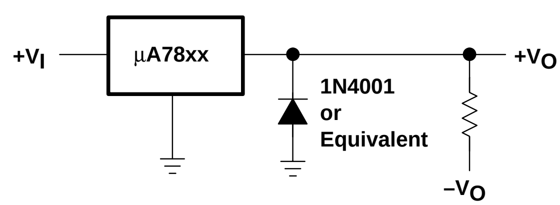


Figure 6. Output Polarity-Reversal-Protection Circuit

reverse-bias protection

Occasionally, the input voltage to the regulator can collapse faster than the output voltage. This can occur, for example, when the input supply is crowbarred during an output overvoltage condition. If the output voltage is greater than approximately 7 V, the emitter-base junction of the series-pass element (internal or external) could break down and be damaged. To prevent this, a diode shunt can be used as shown in Figure 7.

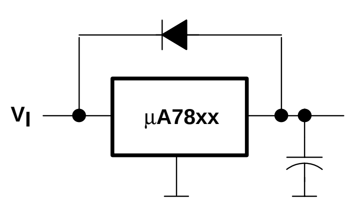
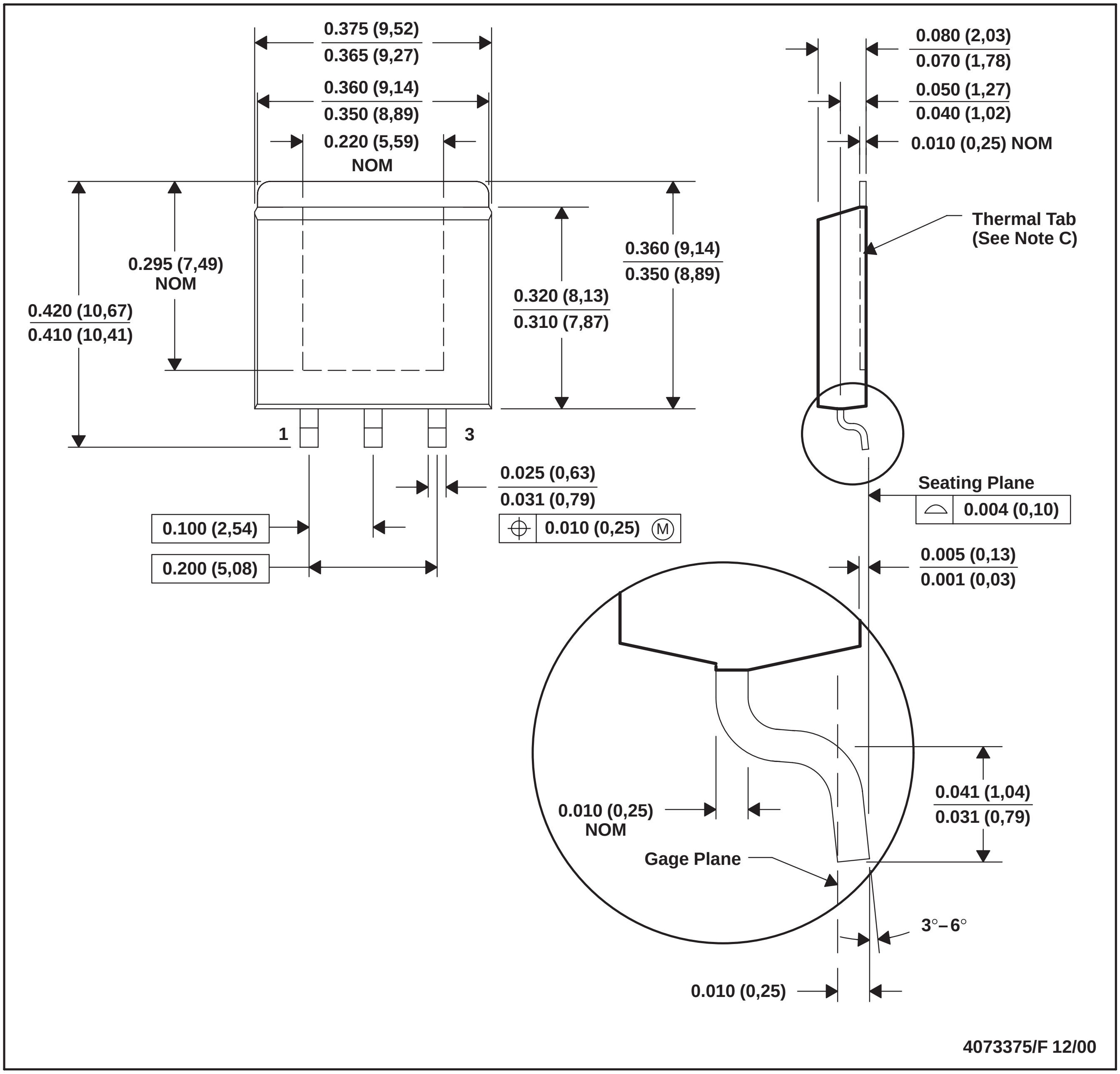


Figure 7. Reverse-Bias-Protection Circuit

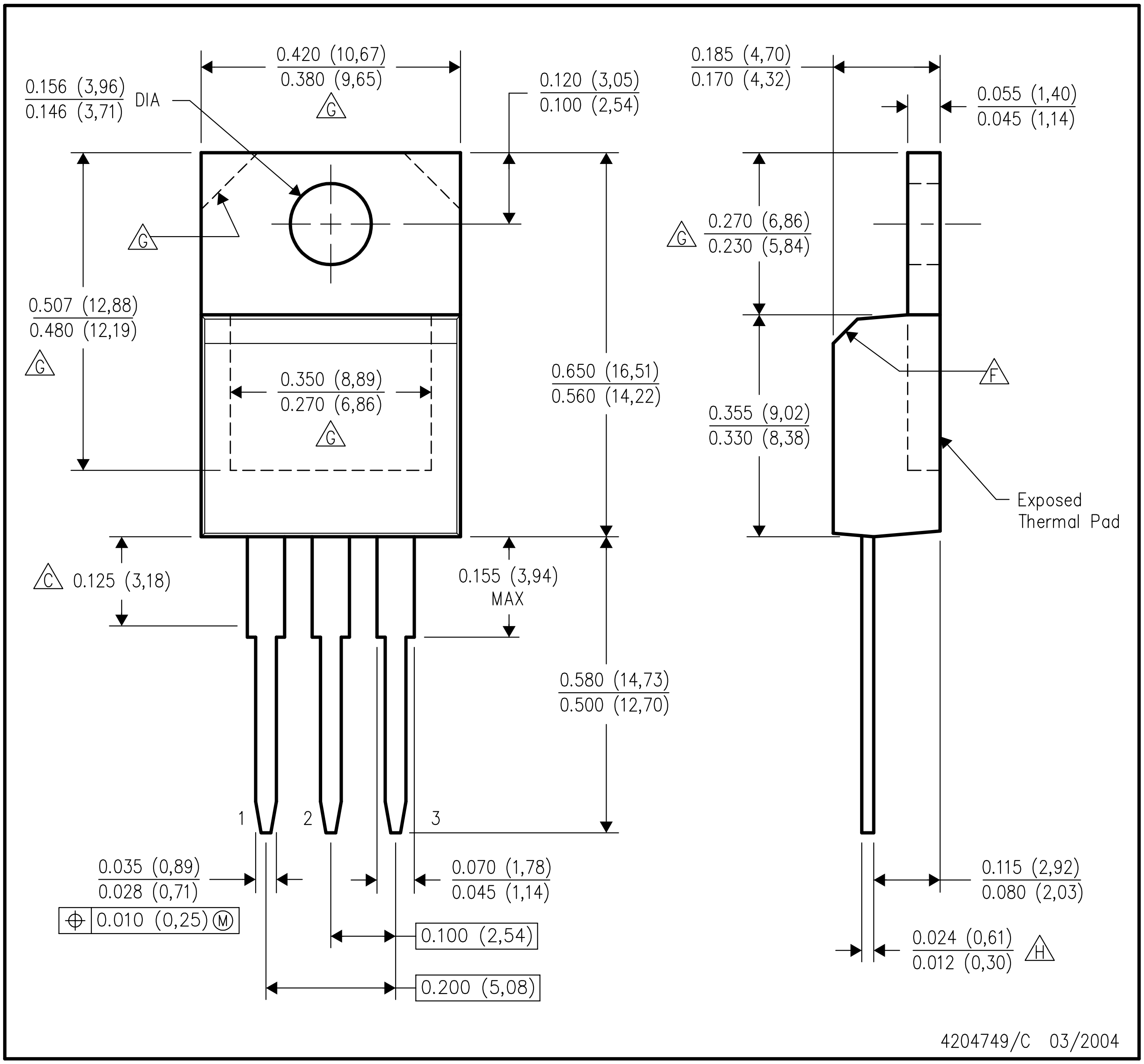
KTE (R-PSFM-G3) **PowerFLEX™ PLASTIC FLANGE-MOUNT**



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. The center lead is in electrical contact with the thermal tab.
D. Dimensions do not include mold protrusions, not to exceed 0.006 (0,15).
E. Falls within JEDEC MO-169

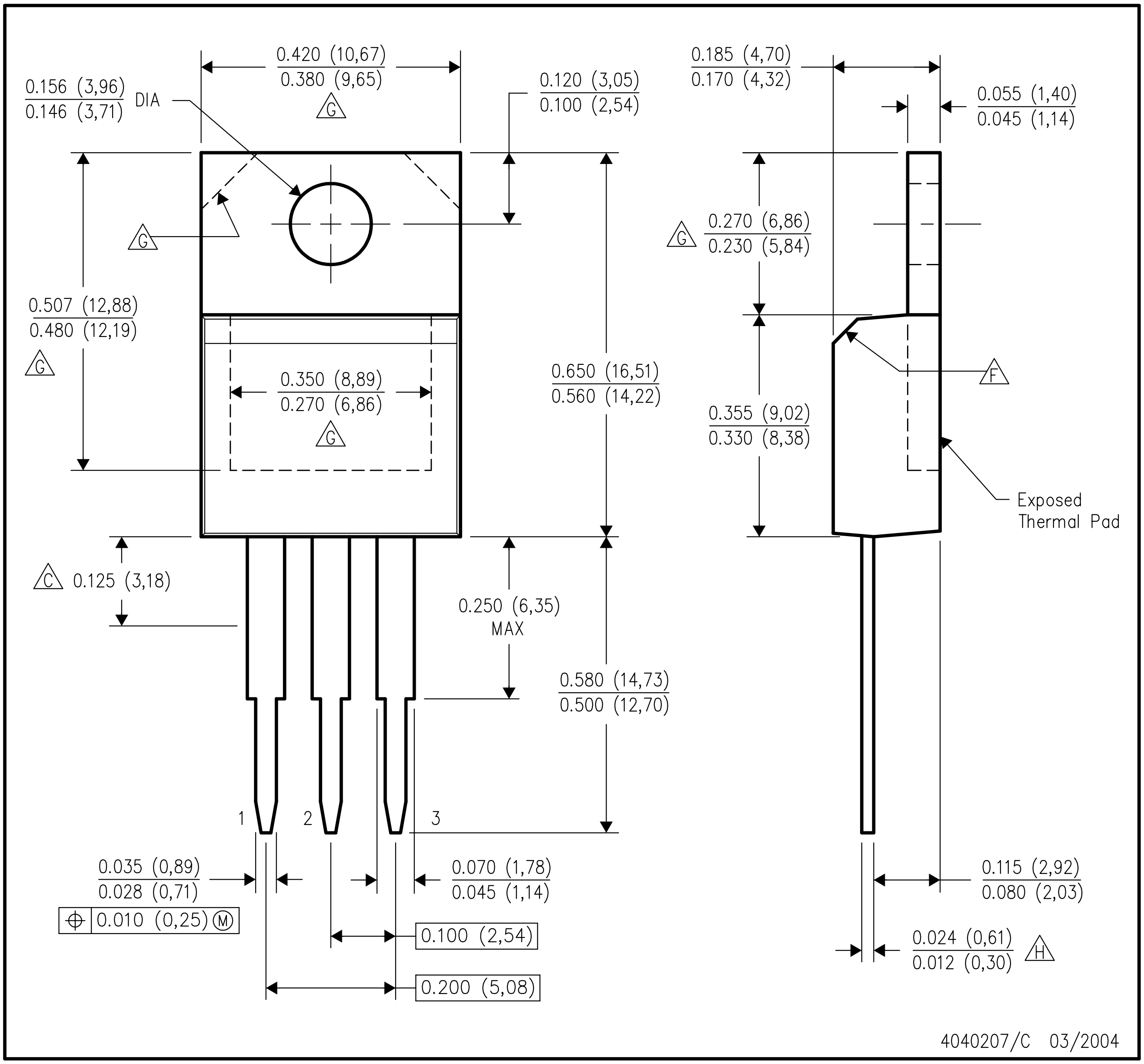
PowerFLEX is a trademark of Texas Instruments.

KCS (R–PSFM–T3) PLASTIC FLANGE–MOUNT PACKAGE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Lead dimensions are not controlled within this area.
- D. All lead dimensions apply before solder dip.
- E. The center lead is in electrical contact with the mounting tab.
- F. The chamfer is optional.
- G. Thermal pad contour optional within these dimensions.
- H. Falls within JEDEC TO–220 variation AB, except minimum lead thickness.

KC (R–PSFM–T3) PLASTIC FLANGE–MOUNT PACKAGE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Lead dimensions are not controlled within this area.
- D. All lead dimensions apply before solder dip.
- E. The center lead is in electrical contact with the mounting tab.
- F. The chamfer is optional.
- G. Thermal pad contour optional within these dimensions.
- H. Falls within JEDEC TO–220 variation AB, except minimum lead thickness.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

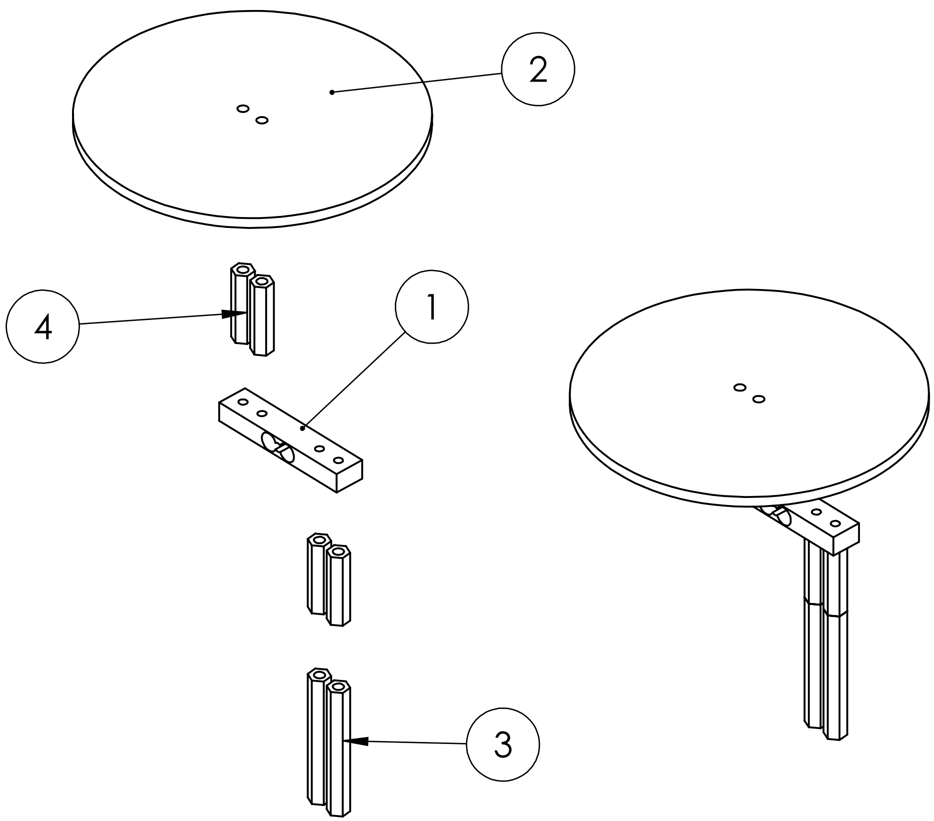
Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

ITEM NO.	PART NUMBER	DESCRIPTION	MATL.	QTY.
1	B801	LOAD CELL	--	1
2	B802	WINE GLASS PLATE	ALUM.	1
3	B803	HOUSING WEIGHT STANDOFF	--	2
4	B804	PLATE WEIGHT STANDOFF	--	4
5	B805	M3X12 BUTTON HEAD CAP SCREW	--	2
6	B806	WINE GLASS PLATE COVER	RUBBER	1

PURCHASED PARTS
B801
B803
B804
B805
B806

MANUFACTURED/ MODIFIED PARTS
B802

PARTS NOT SHOWN:
5 B805 M3X12 BUTTON HEAD CAP SCREW
6 B806 WINE GLASS PLATE COVER

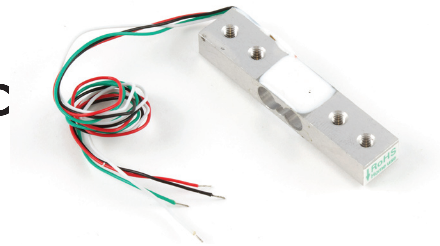


Cal Poly Mechanical Engineering SENIOR PROJECT	Material: SEE BOM		Title:WEIGHT SENSOR ASSEMBLY		Drwn. By: JULIA TRENKLE
	Dwg. #: B800	Nxt Asb: A100	Date: 5/30/2018	Scale: 1:2	Chkd. By: BERKELEY DAVIS

Wine Opener P/N: B801

Datasheet

3132 - Micro Load Cell (0-780g) - CZL616C



Contents

What do you have to know?

A load cell is a force sensing module - a carefully designed metal structure, with small elements called strain gauges mounted in precise locations on the structure. Load cells are designed to measure a specific force, and ignore other forces being applied. The electrical signal output by the load cell is very small and requires specialized amplification. Fortunately, the 1046 PhidgetBridge will perform all the amplification and measurement of the electrical output.

Load cells are designed to measure force in one direction. They will often measure force in other directions, but the sensor sensitivity will be different, since parts of the load cell operating under compression are now in tension, and vice versa.

How does it work - For curious people

Strain-gauge load cells convert the load acting on them into electrical signals. The measuring is done with very small resistor patterns called strain gauges - effectively small, flexible circuit boards. The gauges are bonded onto a beam or structural member that deforms when weight is applied, in turn deforming the strain-gauge. As the strain gauge is deformed, it's electrical resistance changes in proportion to the load.

The changes to the circuit caused by force is much smaller than the changes caused by variation in temperature. Higher quality load cells cancel out the effects of temperature using two techniques. By matching the expansion rate of the strain gauge to the expansion rate of the metal it's mounted on, undue strain on the gauges can be avoided as the load cell warms up and cools down. The most important method of temperature compensation involves using multiple strain gauges, which all respond to the change in temperature with the same change in resistance. Some load cell designs use gauges which are never subjected to any force, but only serve to counterbalance the temperature effects on the gauges that measuring force. Most designs use 4 strain gauges, some in compression, some under tension, which maximizes the sensitivity of the load cell, and automatically cancels the effect of temperature.

Installation

This Single Point Load Cell is used in small jewelry scales and kitchen scales. It's mounted by bolting down the end of the load cell where the wires are attached, and applying force on the other end in the direction of the arrow. Where the force is applied is not critical, as this load cell measures a shearing effect on the beam, not the bending of the beam. If you mount a small platform on the load cell, as would be done in a small scale, this load cell provides accurate readings regardless of the position of the load on the platform.

Calibration

A simple formula is usually used to convert the measured mv/V output from the load cell to the measured force:

$$Measured\ Force = A * Measured\ mV/V + B \text{ (offset)}$$

It's important to decide what unit your measured force is - grams, kilograms, pounds, etc.

This load cell has a rated output of 0.8±0.1mv/v which corresponds to the sensor's capacity of 780g.

To find A we use

$$Capacity = A * Rated\ Output$$

$$A = Capacity\ /\ Rated\ Output$$

$$A = 780\ /\ 0.8$$

$$A = 975$$

Since the Offset is quite variable between individual load cells, it's necessary to calculate the offset for each sensor. Measure the output of the load cell with no force on it and note the mv/V output measured by the PhidgetBridge.

Offset = 0 - 975 * Measured Output

Product Specifications

Mechanical	
Housing Material	Aluminum Alloy
Load Cell Type	Strain Gauge
Capacity	780g
Dimensions	45.16x9.32x6mm
Mounting Holes	M3 (Screw Size)
Cable Length	210mm
Cable Size	30 AWG (0.2mm)
Cable - no. of leads	4
Electrical	
Rated Output	0.8±0.1 mv/V
Non-Linearity	0.05% FS
Hysteresis	0.05% FS
Non-Repeatability	0.05% FS
Creep (per 30 minutes)	0.1% FS
Temperature Effect on Zero (per 10°C)	0.05% FS
Temperature Effect on Span (per 10°C)	0.05% FS
Zero Balance	±1.5% FS
Input Impedance	1090±10 Ohm
Output Impedance	1000±10 Ohm
Insulation Resistance (Under 50VDC)	≥5000 MOhm
Excitation Voltage	5 VDC
Compensated Temperature Range	-10 to ~+40°C
Operating Temperature Range	-20 to ~+55°C
Safe Overload	120% Capacity
Ultimate Overload	150% Capacity

Glossary

Capacity
The maximum load the load cell is designed to measure within its specifications.

Creep
The change in sensor output occurring over 30 minutes, while under load at or near capacity and with all environmental conditions and other variables remaining constant.

FULL SCALE or FS
Used to qualify error - FULL SCALE is the change in output when the sensor is fully loaded. If a particular error (for example, Non-Linearity) is expressed as 0.1% F.S., and the output is 1.0mV/V, the maximum non-linearity that will be seen over the operating range of the sensor will be 0.001 mV/V. An important distinction is that this error doesn't have to only occur at the maximum load. If you are operating the sensor at a maximum of 10% of capacity, for this example, the non-linearity would still be 0.001mV/V, or 1% of the operating range that you are actually using.

Hysteresis
If a force equal to 50% of capacity is applied to a load cell which has been at no load, a given output will be measured. The same load cell is at full capacity, and some of the force is removed, resulting in the load cell operating at 50% capacity. The difference in output between the two test scenarios is called hysteresis.

Excitation Voltage
Specifies the voltage that can be applied to the power/ground terminals on the load cell. In practice, if you are using the load cell with the PhidgetBridge, you don't have to worry about this spec.

Input Impedance
Determines the power that will be consumed by the load cell. The lower this number is, the more current will be required, and the more heating will occur when the load cell is powered. In very noisy environments, a lower input impedance will reduce the effect of Electromagnetic interference on long wires between the load cell and PhidgetBridge.

Insulation Resistance
The electrical resistance measured between the metal structure of the load cell, and the wiring. The practical result of this is the metal structure of the load cells should not be energized with a voltage, particularly higher voltages, as it can arc into the PhidgetBridge. Commonly the load cell and the metal framework it is part of will be grounded to earth or to your system ground.

Maximum Overload
The maximum load which can be applied without producing a structural failure.

Non-Linearity
Ideally, the output of the sensor will be perfectly linear, and a simple 2-point calibration will exactly describe the behaviour of the sensor at other loads. In practice, the sensor is not perfect, and Non-linearity describes the maximum deviation from the linear curve. Theoretically, if a more complex calibration is used, some of the non-linearity can be calibrated out, but this will require a very high accuracy calibration with multiple points.

Non-Repeatability
The maximum difference the sensor will report when exactly the same weight is applied, at the same temperature, over multiple test runs.

Operating Temperature
The extremes of ambient temperature within which the load cell will operate without permanent adverse change to any of its performance characteristics.

Output Impedance
Roughly corresponds to the input impedance. If the Output Impedance is very high, measuring the bridge will distort the results. The PhidgetBridge carefully buffers the signals coming from the load cell, so in practice this is not a concern.

Rated Output
Is the difference in the output of the sensor between when it is fully loaded to its rated capacity, and when it's unloaded. Effectively, it's how sensitive the sensor is, and corresponds to the gain calculated when calibrating the sensor. More expensive sensors have an exact rated output based on an individual calibration done at the factory.

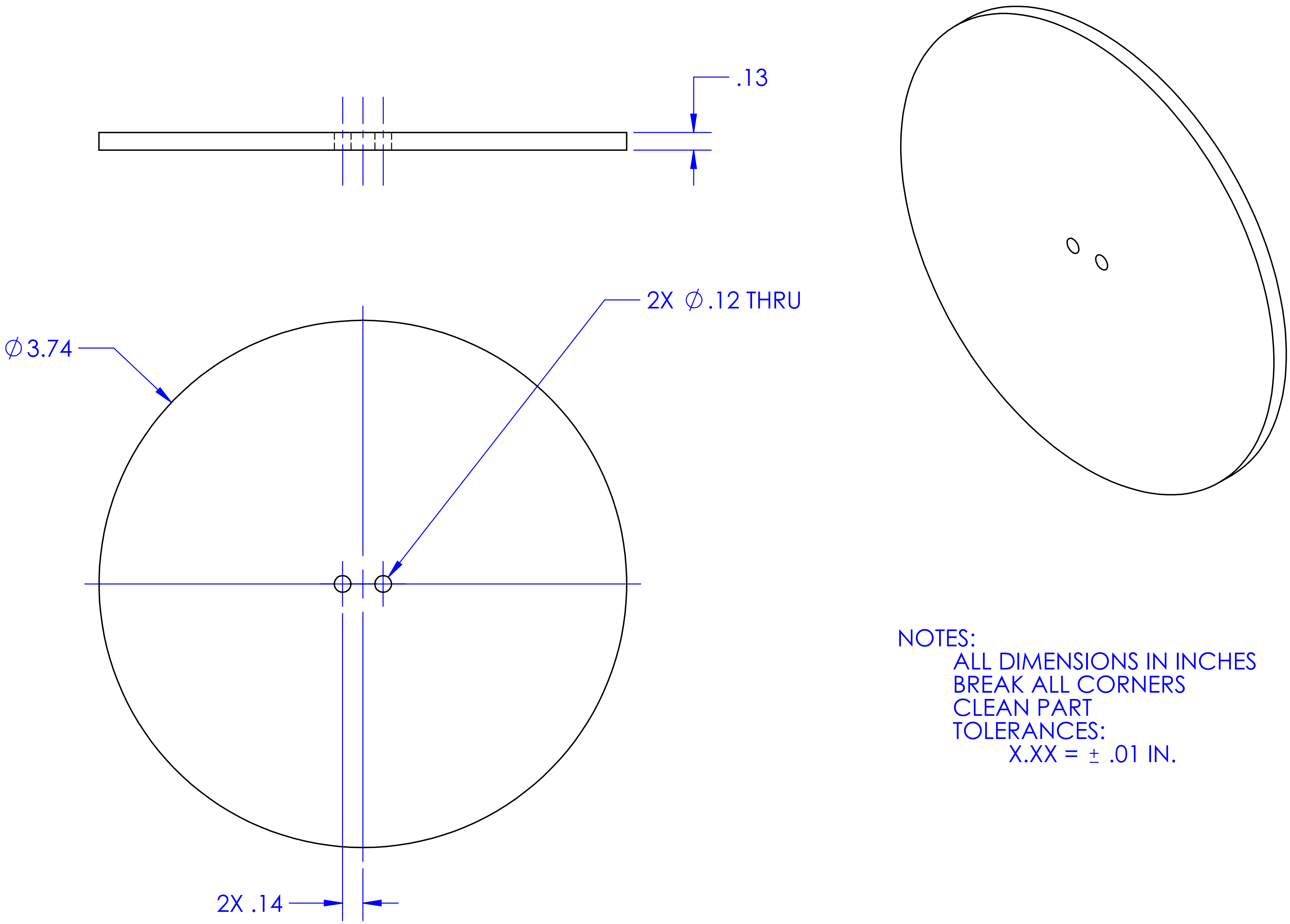
Safe Overload
The maximum axial load which can be applied without producing a permanent shift in performance characteristics beyond those specified.

Compensated Temperature
The range of temperature over which the load cell is compensated to maintain output and zero balance within specified limits.

Temperature Effect on Span
Span is also called rated output. This value is the change in output due to a change in ambient temperature. It is measured over 10 degree C temperature interval.

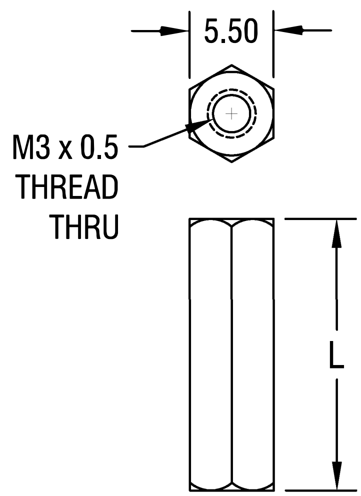
Temperature Effect on Zero
The change in zero balance due to a change in ambient temperature. This value is measured over 10 degree C temperature interval.

Zero Balance
Zero Balance defines the maximum difference between the +/- output wires when no load is applied. Realistically, each sensor will be individually calibrated, at least for the output when no load is applied. Zero Balance is more of a concern if the load cell is being interfaced to an amplification circuit - the PhidgetBridge can easily handle enormous differences between +/-. If the difference is very large, the PhidgetBridge will not be able to use the higher Gain settings.



NOTES:
ALL DIMENSIONS IN INCHES
BREAK ALL CORNERS
CLEAN PART
TOLERANCES:
X.XX = ± .01 IN.

Cal Poly Mechanical Engineering SENIOR PROJECT	Material: ACRYLIC	Title: WINE GLASS PLATE	Drwn. By: BERKELEY DAVIS
	Dwg. #: B802 / Nxt Asb: B800	Date:5/30/2018 / Scale: 1:1	Chkd. By: JULIA TRENKLE



	PART NO.	'L' DIM.
WINE PART NO. B804	24445	15.00
	24446	18.00
WINE PART NO. B803	24447	20.00
	24448	25.00

NOTE:

1. ALL DIMENSIONS ARE IN MILLIMETERS

DATE	DESCRIPTION	REV.

KEYSTONE ELECTRONICS CORP.
ASTORIA, N.Y. 11105-2017

PART NAME: 5.5mm THREADED HEX STANDOFF			
MATERIAL: ALUMINUM			
FINISH: CLEAR IRIDITE		DRN BY: BOONE	DATE: 5.8.06
		APP'D: LN	SCALE: 2X
TOLERANCES INCH [MM] DECIMAL ± [± 0.15] ANGULAR ± 1° UNLESS OTHERWISE SPECIFIED	CODE: C/M	DWG NO.: 24445-24448	

APPENDIX J: RISK ASSESSMENT

<u>Safety Checklist</u>

Y	N	
X	☐	1. Will the system include hazardous revolving, running, rolling, or mixing actions?
X	☐	2. Will the system include hazardous reciprocating, shearing, punching, pressing, squeezing, drawing, or cutting actions?
☐	X	3. Will any part of the design undergo high accelerations/decelerations?
☐	X	4. Will the system have any large (>5 kg) moving masses or large (>250 N) forces?
☐	X	5. Could the system produce a projectile?
☐	X	6. Could the system fall (due to gravity), creating injury?
☐	X	7. Will a user be exposed to overhanging weights as part of the design?
X	☐	8. Will the system have any burrs, sharp edges, shear points, or pinch points?
☐	X	9. Will any part of the electrical systems not be grounded?
☐	X	10. Will there be any large batteries (over 30 V)?
☐	X	11. Will there be any exposed electrical connections in the system (over 40 V)?
☐	X	12. Will there be any stored energy in the system such as flywheels, hanging weights or pressurized fluids/gases?
☐	X	13. Will there be any explosive or flammable liquids, gases, or small particle fuel as part of the system?
☐	X	14. Will the user be required to exert any abnormal effort or experience any abnormal physical posture during the use of the design?
☐	X	15. Will there be any materials known to be hazardous to humans involved in either the design or its manufacturing?
☐	X	16. Could the system generate high levels (>90 dBA) of noise?
☐	X	17. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, or cold/high temperatures, during normal use?
X	☐	18. Is it possible for the system to be used in an unsafe manner?
☐	X	19. For powered systems, is there an emergency stop button?
X	☐	20. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

For any "Y" responses, add (1) a complete description, (2) a list of corrective actions to be taken, and (3) date to be completed on the reverse side.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
Corkscrew may be exposed to the user.	The Cork and Gear team will use a device that covers the corkscrew both while it is in use and when it is not in use so that the user may not cut themselves.	2/20/18	5/15/18
Two sharp blades will squeeze the top of the bottle in order to cut the foil.	The blades are still slightly exposed, but placed in an inconspicuous location. The team will either come up with some sort of protective casing for the blades when they are not in use or will incorporate a warning on the design.	2/20/18	4/21/18
Pinch points.	The casing for the tower presents a couple pinch points wherein a person could potentially be hurt. The case is fully closed while not in operation but will be opened during operation. The edges will be filed so there are no sharp burrs and a warning may be issued for the product.	3/15/18	5/30/18
Liquid in electrical components.	It is possible for wine to be spilled during the used of this product. Electrical components will be encased and sealed to the best of our ability. Fuses will also be used to prevent electrical hazards.	4/1/18	5/30/18
Spilling wine onto floor, causing slipping.	An emergency stop button will be implemented so the pouring can be immediately stopped at any time. This should prevent wine from pooling so much that it overflows onto the floor. We will also recommend having towels near the device during every operation in the Operator's Manual.	4/1/18	5/1/18

designsafe Report

Application:	Novel Wine Opener	Analyst Name(s):	Erin Clark, Berkeley Davis, Jacob Rardin, Julia Trenkle, Brett Wittmuss
Description:	This analysis presents the risks associated with the Novel Wine Opener.	Company:	Center of Effort Winery
Product Identifier:		Facility Location:	Edna Valley, CA
Assessment Type:	Detailed		
Limits:	None		
Sources:	personnel experiences, ANSI B11 standards, assembly drawings W-Z		
Risk Scoring System:	ANSI B11.0 (TR3) Two Factor		

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-1	operator normal operation	mechanical : cutting / severing Foil Cutter/Corkscrew	Moderate Very Likely	High	Warning/Instuctions in Operators Manual	Moderate Remote	Negligible	Complete [6/1/2018] Erin
1-1-2	operator normal operation	mechanical : drawing-in / trapping / entanglement Fingers trapped in foil cutter/corkscrew	Moderate Unlikely	Low	Warning/Instuctions in Operators Manual	Moderate Remote	Negligible	Complete [6/1/2018] Erin
1-1-3	operator normal operation	mechanical : pinch point Closing neck clasp.	Minor Likely	Low	Warning/Instuctions in Operators Manual	Minor Remote	Negligible	Complete [6/1/2018] Erin
1-1-4	operator normal operation	mechanical : unexpected start No Key needed to start	Moderate Unlikely	Low	Require Key to Start	Minor Remote	Negligible	Complete [4/15/2018] Jacob
1-1-5	operator normal operation	mechanical : impact Machine Dropped	Serious Remote	Low	Stabilize Base/ Add rubber feet to base. Warning/Instuctions in Operators Manual	Moderate Unlikely	Low	Complete [5/15/2018] Brett
1-1-6	operator normal operation	slips / trips / falls : slip Wine spilled on floor	Moderate Likely	Medium	Warning/Instuctions in Operators Manual/ Design for minimal Spilling.	Moderate Unlikely	Low	Complete [6/1/2018] Erin/Jacob

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-7	operator normal operation	ergonomics / human factors : lifting / bending / twisting Machine weighing >20 lbs	Moderate Unlikely	Low	Add handles to base for easy transportation. Design for lightweight.	Moderate Unlikely	Low	Complete [4/23/2018] Brett
1-2	operator clean up	<None>						
1-3	operator basic trouble shooting / problem solving	<None>						
1-4-1	operator load / unload materials	slips / trips / falls : impact to / with Wine spilled on floor	Moderate Likely	Medium	Warning/Instuctions in Operators Manual, Operator Training	Minor Remote	Negligible	Complete [6/1/2018] Erin
1-5-1	operator stocking / restocking	mechanical : pinch point Clasping the neck of the bottle/Pivot point of gripper	Minor Likely	Low	Warning/Instuctions in Operators Manual	Minor Remote	Negligible	Complete [6/1/2018] Erin
1-6-1	operator gaging part	mechanical : pinch point Adjusting the clasp for the neck	Minor Likely	Low	Warning/Instuctions in Operators Manual	Minor Unlikely	Negligible	Complete [6/1/2018] Erin
1-7-1	operator clean system	mechanical : drawing-in / trapping / entanglement Taking the cork off the corkscrew/Removing the foil from blades.	Moderate Likely	Medium	Warning/Instuctions in Operators Manual /Not Applicable	Minor Unlikely	Negligible	Complete [6/1/2018] Erin
2-1	maintenance technician parts replacement	<None>						
2-2	maintenance technician adjust controls / settings / alignment	<None>						

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
2-3-1	maintenance technician periodic maintenance	mechanical : cutting / severing Replacing foil cutting blades	Serious Likely	High	Maintenance technician to wear gloves. Specific Procedure and Instructions in Operators Manual including Warning	Minor Unlikely	Negligible	Complete [6/1/2018] Erin
2-3-2	maintenance technician periodic maintenance	mechanical : pinch point Replacing foil cutting blades	Minor Likely	Low	Maintenance technician to wear gloves. Specific Procedure and Instructions in Operators Manual	Minor Remote	Negligible	Complete [6/1/2018] Erin
2-3-3	maintenance technician periodic maintenance	mechanical : unexpected start No key needed for start	Moderate Unlikely	Low	Require key for start. /Not Applicable	Moderate Remote	Negligible	Complete [4/23/2018] Jacob
2-3-4	maintenance technician periodic maintenance	electrical / electronic : energized equipment / live parts No key needed for start	Moderate Unlikely	Low	Require key for start. /Not Applicable	Moderate Remote	Negligible	Complete [4/23/2018] Jacob
2-3-5	maintenance technician periodic maintenance	ergonomics / human factors : lifting / bending / twisting Lifting machine/opening electronics box for access.	Moderate Unlikely	Low	Electronics box to be accessible from the back.	Minor Unlikely	Negligible	In-process Brett
3-1	passer by / non-user walk near machinery	<None>						
3-2	passer by / non-user misuse - doing stupid drunk people things	<None>						
4-1-1	Transporter Common Tasks	mechanical : pinch point No handles specific for carrying machine/gripping the housing or tower.	Minor Likely	Low	Warning/Instuctions in Operators Manual. Add handles to base for easy transportation.	Minor Unlikely	Negligible	Complete [4/23/2018] Brett

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
4-1-2	Transporter Common Tasks	electrical / electronic : shorts / arcing / sparking Wine spilled into electronics box.	Moderate Unlikely	Low	Create seal from top of base structure into electronics box to ensure liquid proof.	Moderate Unlikely	Low	Action Item [6/4/2018] Jacob
4-1-3	Transporter Common Tasks	electrical / electronic : water / wet locations Wine spilled onto base/platform.	Minor Likely	Low	Warning/Instuctions in Operators Manual	Minor Unlikely	Negligible	Complete [6/1/2018] Erin
4-1-4	Transporter Common Tasks	electrical / electronic : power supply interruption Cords break/battery runs out.	Minor Remote	Negligible	Linear Actuator to hold position if disconnected from power.	Minor Remote	Negligible	Complete [5/20/2018] Jacob
4-1-5	Transporter Common Tasks	ergonomics / human factors : lifting / bending / twisting Machine weighs >20 lbs/awkward to carry with tool tower.	Moderate Likely	Medium	Issue weight warning in Operators Manual/ Pick materials for light weight product.	Minor Unlikely	Negligible	Complete [6/1/2018] Erin

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurence	Current Detection Activities	Detection	Priority	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	Severity	Occurence	Criticality
Tower / open bottle	improper engagement	Breaks cork	5	corkscrew not heavy enough	Add weight to corkscrew attachment	4	Check cork engagement (depth)	1	20	Test dry corks if possible	5/18/18	Initial tests with stuck corks completed	6	6	36
		Miss cork engagement	4	rotating base does not rotate to proper angle	program UI to be accurate	3	Check cork engagement (alignment)	1	12	Adjust programming	5/18/18	Tower angle accuracy and physical location checked	6	3	18
			4	linear actuator does not move far enough/too far	program UI to be accurate	4	Check cork engagement (alignment)	1	16	Not Relevant- Corkscrew mounted on free floating gantry	---	---	-	-	-
	not enough force	Cannot remove cork	7	motor/ gearbox does not provide enough torque	Spec motor with additional allowance	6	Observe cork removal process	1	42	Test many different bottles	5/18/18	Tested on multiple different types of corks	7	6	42
		Corkscrew does not enter cork	3	free floating gantry not heavy enough	add weight to gantry	2	Inspect that the corkscrew goes into the cork	1	6	Test the corkscrew with multiple different corks	2/5/18	Corkscrew is able to engage different types of corks	3	1	3
Tower / automation	tool misalignment	auto. tasks incomplete	7	linear actuator does not move far enough/too far	program UI to be accurate	4	Check cork/foil engagement (depth)	1	28	Test the programming on structural prototype	5/18/18	Foil cutter redesigned and gradual cutting method developed	1	1	1
		task interruption	7	rotating base does not rotate to proper angle	program UI to be accurate	3	Check cork/foil engagement (alignment)/rotation away	1	21	Adjust Programming	5/18/18	Tower angle accuracy and physical location checked	6	3	18
Tower / aesthetic	ugly design	doesn't look good	4	casings/attachment were designed without nice aesthetics	Design a tower that looks nice	2	Verify designs with sponsor; inspect device during operation from all angles	3	24	Make sure that current aesthetic is manufacturable and works with design	3/15/18	Housing designs finalized and approved by sponsor	4	7	84
Tower / remove foil	not enough force	cannot pull foil	5	motors for linear actuators do not provide enough torque	Using a strong enough motor	4	Check if foil was removed	1	20	Determine if slip or disengagement	2/5/18	Foil cutter redesigned and gradual cutting method developed	6	6	36
		incomplete cut	4	dull blades	Use sharp blades and have replacements that can be easily switched out	6	Check foil and bottle on a regular basis for worn cutters	3	72	Develop plan for when to replace blades/ test how quickly they dull	5/18/18	Blade replacement instructions included in Operator's Manual	5	2	30
	tool misalignment	cannot pull foil	5	linear actuator does not move down far enough/too far	program UI to be accurate	4	Check foil engagement (depth)	1	20	Attach the blades a fixed distance from the platform that carries them	2/5/18	Cutter tools redesigned	1	1	1
		incomplete cut	4	rotating base does not rotate to proper angle	program UI to be accurate	3	Check foil engagement all around neck (depth)	1	12	Rotate the blades around the bottle multiple times	2/5/18	Control program makes multiple passes	6	3	18
		miss foil engagement	7	rotating base does not rotate to proper angle	program UI to be accurate	3	Check foil engagement (alignment)	1	21	Adjust Programming	2/5/18	Control program designed with gradual cuting	6	3	18
	insecure grasping point	miss foil engagement	7	linear actuator does not move down far enough/too far	program UI to be accurate	4	Check foil gripping depth	1	28	Not Relevant - Foil removal mechanism attached to free floating gantry	----	---	-	-	-
		incomplete removal	5	linear actuator does not move down far enough/too far	program UI to be accurate	4	Check foil gripping depth and pull distance	1	20	Test feasibility of removing foil with the blades	2/5/18	Foil cutter is able to pull off cut foils	1	1	1
Tower / structure	buckling (overloading)	cracking	8	Gantries are too stiff on linear actuator	design with a free floating and powered gantry	1	Check for bending in the tower	5	40	Inspect tower during testing	5/6/18	Inspection	1	1	5
		Bending	2	Gantries are too stiff on linear actuator	design with a free floating and powered gantry	2	Attempt slight overload of system to check handling	4	16	Inspect tower during testing	5/6/18	Inspection	1	1	4
	wobbly movement	Loosening	2	fasteners too loose	tighten fasteners	3	Check for wobbly movement of tower	1	6	Double check assembly and inspect during testing	5/6/18	Inspection	3	1	3
		Bending	2	fasteners coming out	tighten fasteners	2	Check fasteners conditions periodically	3	12	Double check assembly and inspect during testing	5/6/18	Inspection	3	1	9
	vibrations	Loosening	3	motor not secured down properly	secure motor to base by tightening fasteners	2	Check system for vibration throughout motion	2	12	Mount the motor away from the base	5/6/18	Motor mounted away from base	5	1	10
	shearing	cracking	8	attatchments are compromising tower when performing functions	design with a free floating and powered gantry	2	Check full range of motion for interference	2	32	Inspect tower during testing - free floating gantry	5/6/18	Inspection	6	4	48

	fatigue	Bending, cracking	8	over time the wear on the system strains the components	use components that have long life and have replacements	1	Perform endurance tests on system and visually inspect	7	56	Overdesign components for safety and longevity	5/6/18	Overdesigned	2	1	14
	overtightening	unable to move	4	fasteners too tight	loosen fasteners/use dynamic bolts	3	Check for strained movement of tower	1	12	Double check assembly and inspect during testing	5/6/18	Inspection	2	1	2
Pouring / pour bottle	cannot lift bottle	cannot pour	8	broom clip not stiff enough	consider new gripper, use thicker material	6	Test broom clip range of use	2	96	Look into alternatives, such as a spring-loaded clip or support from bottom- Not relevant	----	Gripping mechanism has been redesigned	-	-	-
			7	Setscrews not tight enough	Add rubber padding to ends	6	Test stability of bottle throughout pour	2	84	Test abiltiy of setscrews to hold dry and wet bottles	2/22/18	Bottle is able to be gripped rigidly	5	2	20
			8	rubber coating does not provide enough friction	increase coating layer	7	Test effectiveness of rubber coating	1	56	Use set screws with rubber padding	5/14/18	Still testing screw covers	5	2	20
	structure fails	miss glass	4	linkage system doesn't rotate to correct position	program UI to be accurate	7	Test repeatedly for accuracy	1	28	Not Relevant	----	---	-	-	-
		splashing	1	motor moves too quickly	use a motor that is precise	6	Test for splashing	1	6	Adjust Programming	5/14/18	No splashing, but pours sometimes drip	7	4	7
		cannot pour	7	motor doesn't provide enough torque	Using a strong enough motor	6	Test for linkage movement with weight of wine and bottle	1	42	Do more analysis if current motor does not work and get new motor	3/15/18	Pouring system is sufficient to control rotation	9	8	80
		breaks pouring mechanism	8	linkage system not sturdy enough	Design with factor of safety	2	Check for breakage	1	16	Not Relevant	----	---	-	-	-
Pouring / automation	takes too long to pour	task interruption	5	motor not fast enough	Use a motor that is fast enough	6	Check overlap of tasks	1	30	Adjust Programming	3/15/18	Control program can be adjusted for speed	5	4	5
	tool misalignment	automatic tasks incomplete	8	linkage system not sturdy enough	tighten tolerances between linkages	3	Perform endurance tests on system	1	24	Not Relevant	----	---	-	-	-
Pouring / aesthetic	ugly design	doesn't look good	3	casings/attachment were designed without nice aesthetics	Design a pouring mechanism that looks nice	2	Verify designs with sponsor; inspect device during operation from all angles	2	12	Brainstorm more ideas for the casing	4/12/18	Housing designs finalized and approved by sponsor	5	7	70
	component wear	doesn't look good	2	rubbing components scratch surface finish	include spacers, round edges	5	inspect surfaces for wear	2	20	Check interference during testing	5/18/18	Inspected and corrected	3	3	30
Gripping / secure bottle	not enough force	cannot grip bottle (spin/lift); cannot maintain grip (drop/slip)	7	broom clip not stiff enough	Increase material thickness	6	Test broom clip range of use	2	84	Test broom clip range of use, range of thickness effectiveness, look into alternatives- Not relevant	----	New gripper design holds bottle securely	-	-	-
	not enough friction	cannot grip bottle (spin/lift); cannot maintain grip (drop/slip)	7	rubber pads on setscrews does not provide enough friction	Increase coating layer	7	Test effectiveness of rubber pads	3	147	Test on wet bottles; test a variety of coatings and gripping methods	4/12/18	New gripper design holds bottle securely	5	2	20
		cannot maintain grip (drop/slip)	7	rubber coating does not provide enough friction	Increase coating layer	4	Test effectiveness of rubber coating	2	56	Test on wet bottles	4/12/18	New gripper design holds bottle securely	5	2	20
	component misalignment	breaks gripper	7	user places bottle incorrectly into gripper (too high/low)	Design one orientation; add sensor at bottom of bottle	2	Observe bottle orientation	2	28	Not relevant	----	---	-	-	-
		Bottle has vertical movement in gripper	4	top clamp not tight enough or located correctly	set clamp to lowest part of the bottle possible	3	Inspect bottle movement	1	12	Adjust clamp location	4/12/18	Final gripper design includes tuning from prototype	4	2	20
Sense weight / automation	incorrect volume read	automatic tasks incomplete	5	pressure sensor does not null the initial spike in weight as the first amount of wine hits the bottom of the glass	Configure pressure sensor, make pour soft enough	8	Oscilloscope with computer real time readings, measure volume poured in graduated cylinder to verify amount	2	60	Change software to accomodate for initial wine, change pour to soften initial impulse, change direction of flow on glass, change orientation of glass setup	5/18/18	Pouring controller gives precise readout; accuracy has not been tested yet	3	7	70
	takes too long to measure	task interruption	5	pressure sensor does not read at a fast enough rate	Use a fast reading pressure sensor	3	Observe real time readings	1	15	Adjust motor in relation to load cell	4/12/18	Weight readings can be taken quickly enough	6	7	70
Sense weight / aesthetic	ugly design	doesn't look good	3	casings/attachment were designed without nice aesthetics	Design a covering (pedestal) that covers critical components and looks nice	2	Verify designs with sponsor; inspect device during operation from all angles	2	12	Place load cell in cutout of base, and secure with rubber ring to prevent spilling	5/18/18	Pouring target plate should be flush with base	5	6	60
UI / automation	bad inputs received	automatic tasks incomplete	8	control panel wired incorrectly/wiring faults	Wire it correctly/use insulation	2	Test interface with unintended operations	2	32	Adjust Programming	5/18/18	Programming adjusted	8	5	8

	options do not display correctly	user annoyance	3	display/feedback not set up correctly	set up display correctly	5	Test different (unintended) scenarios for bad feedback	1	15	Adjust UI	5/18/18	UI adjusted	8	8	8
UI / aesthetic	component wear	doesn't look good	2	buttons get damaged with use	Have replacement buttons readily available	2	inspect buttons	4	16	Order sturdy buttons/switches, make sure they are easily replaced	5/18/18	Ordered sturdy hardware	2	1	10
	bad layout	doesn't look good	1	control panel was designed without nice aesthetics	Design control panel to have nice aesthetics	2	Verify designs with sponsor; inspect device during operation from all angles	1	2	Send UI options to sponsor to get feedback	2/22/18	Sponsor has approved UI design	2	1	2
UI / pour variety	software bugs	inaccurate volume	2	software not thorough	Make sure software accounts for all system bugs; design debugging routines	4	"Stress test" software for unintended use	7	56	Start writing software as soon as components are available	5/18/18	Software debugged	5	3	30
Housing / aesthetic	ugly design	doesn't look good	3	housing was designed without nice aesthetics	Design housing with nice aesthetics	2	Verify designs with sponsor; inspect device during operation from all angles	2	12	Sponsor has approved current housing/ Begin building	4/10/18	Housing designs finalized and approved by sponsor	5	4	5
		surface corrosion	3	weather conditions that produce rust, dirt	Surface finish exposed regions	2	inspect exterior surfaces over time	5	30	Make housing with good materials	5/18/18	Made with sturdy hardware	2	1	10
Housing / structure	vibrations	Loosening	3	motor not secured down properly	Tighten fasteners securing motor to structure; add dampeners	4	Conduct extended motor runs to check for gradual loosening	4	48	Secure motor away from base structure	5/18/18	Motor secured away from base	7	3	30
	fatigue	Bending, cracking	8	over time, wear on the system strains the coverings	design to minimize excess wear or loading on components	1	Test full ranges of motion for interference	4	32	Double check assembly and inspect during testing	5/18/18	Inspection	3	1	10
	overtightening	unable to move	4	housing attached too tightly to moving components	add bearings/bushings and/or lubiricant	2	Check joints for smooth motion	1	8	Double check assembly and inspect during testing	5/18/18	Inspection	3	1	10
Housing / protect	liquid ingress	electrical shorts, corrosion	6	design of housing not water-tight	add seals and/or splash guards	3	Protect components, then test with non-conductive fluid	4	72	Perform splash tests where wine is likely to be spilled	5/18/18	Spill tests performed	5	2	20
	debris ingress	unable to move	5	design of housing has open spaces that expose critical systems	shield components that can jam, or make them easy to clean	3	Check joints for accessibility and fouling potential	4	60	Test ease of cleaning/maintenance/disassembly	5/18/18	Checked ease of cleaning and maintenance	7	2	20
General / assembly	Poor assembly	parts fall apart	7	poor tolerances between components	measure twice, design once, and double-check	3	Check for loose or sloppy motion	2	42	Double check assembly and inspect during testing	5/18/18	Inspection	4	3	30
General / aesthetic	exposed screws/systems	doesn't look good	3	lack of covers for exposed screws and systems	add countersinks for screws or cover up parts	2	Verify designs with sponsor; inspect device during operation from all angles	2	12	Find ways to hide welds/screws/ etc. Inspect structural prototype for potential improvements	5/18/18	Housing should cover up most exposed fasteners and parts	2	4	2

APPENDIX K: DESIGN VERIFICATION & TESTING

Senior Project DVP&R

Date: 31 May 2018	Team: Cork & Gear	Sponsor: Center of Effort Winery	Description of System: Device for opening and pouring a bottle of wine	DVP&R Engineers: Erin Clark, Berkeley Davis

TEST PLAN										TEST REPORT			
Item No	Specification #	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	1	Centering the foil cutter	Must engage the bottle every time (test 8+ times), Test	Julia	SP	1	Sub	5/1/18	5/18/18	Pass	8	0	Centered every time
2	2	Centering the corkscrew	Must engage the bottle every time (test 8+ times), Test	Brett	SP	1	Sub	5/1/18	5/18/18	Pass	8	0	Corkscrew does not need to be directly in the center of the cork when pulling
3	3	Pulling the cork without spilling	8+ successful cork removals, Test	Julia	SP	1	Sub	3/16/18	4/2/18	Pass	8	0	No issues with rapid cork removal causing spilling
4	4	Pulling dry corks out	5 successful dry cork removals, Test	Brett	SP	1	Sub	5/1/18	5/10/18	Pass	5	0	On test 2 the cork was pulled half way out, but was successful when corkscrew operation was run again
5	5	Make sure foil is fully cut	Full cut 8+ times, Inspection	Julia	SP	1	Sub	5/1/18	5/18/18	Pass	8	0	In test 6, the foil bunched and tore slightly on one of the rotations, however the foil was still fully cut and removed
6	6	Make sure foil is fully removed with the blades	Successful 4/5 times, Inspection	Julia	SP	1	Sub	5/1/18	5/18/18	Pass	5	0	Tightness of servo motors were adjusted upon calibration of the machine
7	7	Test how quickly the blades get dull	As many foil cuts as it takes to dull the blades, Inspection	Julia	SP	1	C	3/16/18	6/1/18	Unknown	---	---	We do not have enough time or bottles to determine the blade life via testing
8	8	Check if the floating part of the tower is heavy enough to drive the corkscrew	Find necessary weight, Analysis and Inspection	Brett	SP	1	C	4/15/18	5/5/18	Pass	1	0	Corkscrew immediately drives into bottle
9	9	Test if motor is able to move the bottle in small/proper increments	5 incremental pours using the motor, Test	Jacob	SP	1	Sub	4/2/18	4/27/18	Pass	5	0	Motor angle accurate within 0.5 degree criteria
10	10	Check if the pour is clean/doesn't spill	5 successful clean pours from start of bottle to finish, Inspection	Berkeley	SP	1	C	4/15/18	5/1/08	Fail	1	4	Small drips or dribbles down the side of the glass occur more often than not
11	11	Make sure bottle does not slide vertically in the gripper at any stage of the process	Pours without bottle movement, Inspection	Berkeley	FP	1	C	5/1/18	5/11/18	Pass	1	0	Gripper does not slip
12	12	Check the sensitivity/accuracy of the load cell	Compare weights with known accurate devices, Test and Compare	Erin	SP	1	C	3/4/18	3/8/18	Pass	8	0	within 1% of known weights
13	13	Test correspondence of the motor lifting the bottle in relation to the load cell	Test the reaction timing when the code is implemented, Test	Jacob	FP	1	Sub	4/16/18	5/5/18	Fail	8	7	For +/- 5% tolerance, pouring controller fails about 50% of the time; for +/- 10% tolerance, pouring controller only failed 1 time out of 15 tests
14	14	Check that the UI works properly	Complete 8+ bottle openings using the UI, Test	Erin	FP	1	Sys	5/7/18	5/25/18	Pass	8	0	When switching the controller off while operating, the machine will stop and hold current position
15	15	Operation Time	Less than 90 seconds	Erin	FP	1	Sys	5/7/18	5/26/18	Pass	10	0	86 second operation time

TEST SUMMARY

Test #	Test Name	Pass/Fail
1	Foil Cutter Centered	Pass
2	Corkscrew Centered	Pass
3	Removes Typical Corks	Pass
4	Removes Dry Corks	Pass
5	Fully Cut Foil	Pass
6	Foil Fully Removed	Pass
7	Blade Life	Fail
8	Floating Gantry Drives the Corkscrew	Pass
9	Pouring Motor Tilts to Specific Angle	Pass
10	Pouring is Clean	Fail
11	Vertical Slipping of Wine Bottle	Pass
12	Rotational Slippage of Wine Bottle	Pass
13	Accuracy of the Load Cell	Pass
14	Amount of Wine Poured	Fail
15	User Interface Works Properly	Pass
16	Emergency/Stop Button Works	Pass
17	Operation Time	Pass
18	Fits Though Doorway	Pass
19	Fits in Car Trunk or Back Seat of Car	Pass
20	Weight	Pass
21	Liquid Ingress	Fail
22	Pulling Cork through Wax Seal	Fail

TEST PROCEDURE

ITEM 1: FOIL CUTTER CENTERED

DESCRIPTION OF TEST:

Rotate linear actuator tower, lower foil cutting mechanism, and check for initial interference between foil cutting blades and top of bottle.

ACCEPTANCE CRITERIA:

The top of the bottle must be placed in the foil cutting area between the foil cutting blades without being interfered by the blades.

REQUIRED MATERIALS:

1. Foil sealed wine bottle

TESTING PROTOCOL:

1. Rotate linear actuator tower.
2. Lower powered linear actuator gantry to lowest possible location.
3. Check for interference.

DATA:

Test #	Interference Pass/Fail (no interference)
1	Pass
2	Pass
3	Pass
4	Pass
5	Pass
6	Pass
7	Pass
8	Pass

Pass / Fail

TEST PROCEDURE

ITEM 1: FOIL CUTTER CENTERED

OBSERVATIONS:

All 8 runs of the machine centered the foil cutter every time.

Pass / Fail

TEST PROCEDURE

ITEM 2: CORKSCREW CENTERED

DESCRIPTION OF TEST:

Rotate linear actuator tower, lower corkscrew mechanism, and check distance between corkscrew and center of cork.

ACCEPTANCE CRITERIA:

Corkscrew must be set within a 0.5 cm radius from the center of the cork.

REQUIRED MATERIALS:

1. Corked wine bottle.
2. Ruler, calipers, or other small-scale measuring tool.
3. 1 cm diameter circle stencil.

TESTING PROTOCOL:

1. Find the center of the cork.
2. Draw a 1 cm diameter circle around center point using stencil.
3. Lower powered linear actuator gantry to lowest possible location.
4. Check if corkscrew is within 1 cm diameter circle.

Pass / Fail

TEST PROCEDURE

ITEM 2: CORKSCREW CENTERED

DATA:

Test #	Distance between corkscrew and center of cork (cm)	Distance Pass/Fail (within 0.5 cm radius)
1	0.40	Pass
2	0.50	Pass
3	0.40	Pass
4	0.17	Pass
5	0.25	Pass
6	0.45	Pass
7	0.41	Pass
8	0.38	Pass

OBSERVATIONS:

Let it be noted that the corkscrew does not need to be directly in the center of the cork when pulling. The design of the electric corkscrew is to enter around 4mm about the center of the cork and drive it upwards as it circles through the cork.

The housing of the corkscrew was designed so that as long as the corkscrew lands on top of the bottle, the corkscrew will always be correctly positioned above the cork. After the 3rd test, the “wiggle” operation was tested and allowed for the corkscrew to land on the top of the bottle even if for some reason it landed on an edge.

Pass / Fail

Note: The corkscrew is around 8 mm wide.

Pass / Fail

TEST PROCEDURE

ITEM 3: REMOVES TYPICAL CORKS

DESCRIPTION OF TEST:

Use mounted electric corkscrew to remove a typical or “fresh” (aka not dry) cork.

ACCEPTANCE CRITERIA:

Cork must be fully removed and must be fully intact.

REQUIRED MATERIALS:

1. Corked wine bottle.
2. Corked and waxed wine bottle.

TESTING PROTOCOL:

1. Manually place corkscrew at center of cork.
2. Actuate electric corkscrew
3. Check for breakage of the cork.
4. Check for full removal of the cork.

DATA:

Test #	Cork Removal Pass/Fail
1	Pass
2	Pass
3	Pass
4	Pass
5	Pass
6	Pass
7	Pass
8	Pass

Pass / Fail

TEST PROCEDURE

ITEM 4: REMOVES DRY CORKS

DESCRIPTION OF TEST:

Use mounted electric corkscrew to remove a dry cork.

ACCEPTANCE CRITERIA:

Cork must be fully removed but does not need to be fully intact.

REQUIRED MATERIALS:

1. Wine bottle with a cork that is known to be dry.

TESTING PROTOCOL:

1. Manually place corkscrew at center of cork.
2. Actuate electric corkscrew
3. Check for full removal of the cork.

DATA:

Test #	Cork Removal Pass/Fail
1	Pass
2	Fail
3	Pass
4	Pass
5	Pass

Pass / Fail

TEST PROCEDURE

ITEM 4: REMOVES DRY CORKS

OBSERVATIONS:

To prepare for this test, we kept 8 bottles in a climate-controlled room in order to dry out the corks. We left 6 bottles there for 4 weeks, and another 2 there for 8 weeks.

Normal operation of the full machine was done instead of manually placing the corkscrew at the center.

On test 2, the cork was pulled half way out. This was because it did not engage well on the first pass. We ran the corkscrew through the operation again and this time it pulled the full cork out without breaking. This was designated as a fail, but the operation overall was overcome and the wine was able to be poured.

Pass / Fail

TEST PROCEDURE

ITEM 5: FULLY CUT FOIL

DESCRIPTION OF TEST:

Lower and actuate the foil cutting mechanism and check for fullness of cut.

ACCEPTANCE CRITERIA:

The foil must be cut 360 degrees around the bottle.

REQUIRED MATERIALS:

1. Foil sealed wine bottle

TESTING PROTOCOL:

1. Manually place foil cutting mechanism on top of bottle.
2. Actuate linear servos to squeeze the bottle.
3. Actuate foil motor to rotate the blades 180 degrees clockwise, 360 degrees counter clockwise, and a 180 degrees clockwise to return to the initial position.
4. Release linear servos.
5. Manually, slowly and carefully, remove foil while checking for any parts of the foil cap that are still connected to the foil remaining on the bottle.

Pass / Fail

TEST PROCEDURE

ITEM 5: FULLY CUT FOIL

DATA:

Test #	Full Cut Pass/Fail (360°)	Notes
1	Pass	
2	Pass	
3	Pass	
4	Pass	
5	Pass	
6	Pass	See observations
7	Pass	
8	Pass	

OBSERVATIONS:

On test #6, the foil bunched and tore slightly on one of the rotations, however the foil was still fully cut and was able to be removed. All other runs were successful and had very clean cut lines.

Pass / Fail

Pass / Fail

TEST PROCEDURE

ITEM 6: FOIL FULLY REMOVED

DESCRIPTION OF TEST:

Lower foil cutting mechanism onto bottle, actuate foil cutting mechanism, and lift mechanism away from the bottle.

ACCEPTANCE CRITERIA:

Already cut foil cap must be fully removed.

REQUIRED MATERIALS:

1. Wine bottle with foil cut a full 360 degrees but not previously removed from bottle.

TESTING PROTOCOL:

1. Lower powered linear actuator gantry to lowest possible location.
2. Actuate linear servos to squeeze the bottle.
3. Raise the powered linear actuator gantry.
4. Verify that foil has been removed.

DATA:

Test #	Fully Removed Foil Cap Pass/Fail
1	Pass
2	Pass
3	Pass
4	Pass
5	Pass

Pass / Fail

TEST PROCEDURE

ITEM 6: FOIL FULLY REMOVED

OBSERVATIONS:

All foils were removed after adjusting the tightness of the servo motors upon calibration of the machine.

Pass / Fail

TEST PROCEDURE

ITEM 7: BLADE LIFE

DESCRIPTION OF TEST:

Determine how frequently the blades will need to be replaced.

ACCEPTANCE CRITERIA:

No specific acceptance criteria. Test solely for sponsor's information.

REQUIRED MATERIALS:

1. Enough wine bottles to wear out the blades (to be determined during testing).

TESTING PROTOCOL:

1. Cut and remove the foil from a bottle of wine.
2. Count the number of foil removals.
3. Check the effectiveness of the blades to see if they need to be replaced.

DATA:

# of Foil Cuts for Blades to Dull	Notes
UNKNOWN	We were unable to test the life of the blades with the number of bottles provided. This is an ongoing test that would have to be completed post expo.

OBSERVATIONS:

Pass / Fail

TEST PROCEDURE

ITEM 8: FLOATING GANTRY DRIVES THE CORKSCREW

DESCRIPTION OF TEST:

Verify that the free-floating gantry on the linear actuator tower is heavy enough to drive the corkscrew into uncovered corks and wax covered corks.

ACCEPTANCE CRITERIA:

Corkscrew must lodge into wax bottles and regularly corked bottles.

REQUIRED MATERIALS:

1. A wax sealed wine bottle.
2. A regularly corked bottle.

TESTING PROTOCOL:

1. Manually center the corkscrew over top of the wine bottle.
2. Lower powered linear actuator gantry to lowest possible location.
3. Actuate the corkscrew.
4. Check if the corkscrew has successfully lodged itself into the cork.

DATA:

Sufficient Floating Gantry Weight Pass/Fail	Notes
Pass	Corkscrew has immediately driven into the bottle in each of 12 tests

OBSERVATIONS:

Pass / Fail

TEST PROCEDURE

ITEM 9: POURING MOTOR TILTS TO SPECIFIED ANGLE

DESCRIPTION OF TEST:

Verify that the motor rotates to the angle that corresponds to the input angle.

ACCEPTANCE CRITERIA:

The motor will rotate to the angle given by the input ± 0.5°

REQUIRED MATERIALS:

1. Foil sealed wine bottle
2. Leveling phone app.

TESTING PROTOCOL:

1. Attach the phone to the wine bottle.
2. Command motor to rotate to a specific angle.
3. Read and record angle from the leveling phone app.

Test #	Angle (degrees)	Accurate Angle Pass/Fail (± 0.5°)
1	90	Pass
2	35	Pass
3	83	Pass
4	10	Pass
5	100	Pass

OBSERVATIONS:

This test was directly conducted by inputting an angle (<u>in radians)</u> into the code and having the motor turn to the given angle. The motor was very accurate and always fell within the 0.5 degree criteria.

Pass / Fail

TEST PROCEDURE

ITEM 10: POURING IS CLEAN

DESCRIPTION OF TEST:

Pour a tasting size pours starting with a full bottle until the bottle is empty.

ACCEPTANCE CRITERIA:

There will be no amount of wine on the base surface of the machine.

REQUIRED MATERIALS:

1. A foil sealed wine bottle opened by the machine.
2. A wax sealed wine bottle opened by the machine.

TESTING PROTOCOL:

1. Command the machine to pour a tasting size pour.
2. Return the bottle to starting position.
3. Check for wine on the base platform.
4. Repeat until the bottle is empty.

DATA:

Test #	Clean Pour Pass/Fail	Notes
1	**Fail**	One drip onto the side of the glass
2	**Fail**	Dribbling down the side of the bottle
3	**Fail**	Drips onto the side of the glass
4	Pass	
5	**Fail**	Dribbling down the side of the bottle

OBSERVATIONS:

The machine needs a significant rework of the pouring controller to make the pouring clean.

Pass / Fail

TEST PROCEDURE

ITEM 11: VERTICAL SLIPPING OF WINE BOTTLE

DESCRIPTION OF TEST:

Use the device in the intended way to check for movement of the bottle.

ACCEPTANCE CRITERIA:

The bottle must not slip along the vertical axis of the gripper.

REQUIRED MATERIALS:

1. Sharpie.
2. A full, sealed wine bottle. (The heaviest bottle to be opened by the machine.)

TESTING PROTOCOL:

1. Insert the unopened bottle into the gripper mechanism.
2. Secure the gripper mechanism as one would do in a typical application.
3. Use the sharpie to mark a thin, horizontal line just above and below the neck clamp. (Take pictures of the marks for reference.)
4. Use the foil cutting and corkscrew mechanisms to open the bottle.
5. Check for vertical movement of the bottle. (Compare with pictures for verification.)
6. Randomly select a pouring size and command the motor to pour.
7. Return the bottle to its initial position and check for vertical movement.
8. Repeat steps 6 and 7.

DATA:

Vertical Slip Pass/Fail	Notes
Pass	The gripper has yet to slip vertically in over 12 full tests.

Pass / Fail

TEST PROCEDURE

ITEM 12: ROTATIONAL SLIPPAGE OF WINE BOTTLE

DESCRIPTION OF TEST:

Use the device in the intended way to check for movement of the bottle.

ACCEPTANCE CRITERIA:

The bottle must rotate about the vertical axis of the gripper.

REQUIRED MATERIALS:

1. Sharpie.
2. A full, sealed wine bottle. (The lightest bottle to be opened by the machine.)

TESTING PROTOCOL:

1. Insert the unopened bottle into the gripper mechanism.
2. Secure the gripper mechanism as one would do in a typical application.
3. Use the sharpie to mark a thin, vertical line above and below the neck clamp. (Take pictures of the marks for reference.)
4. Use the foil cutting and corkscrew mechanisms to open the bottle.
5. Check for rotational movement of the bottle. (Compare with pictures for verification.)
6. Randomly select a pouring size and command the motor to pour.
7. Return the bottle to its initial position and check for rotational movement.
8. Repeat steps 6 and 7.

DATA:

Rotational Slip Pass/Fail	Notes
Pass	The bottle has yet to slip in the gripper during testing in over 12 tests.

Pass / Fail

TEST PROCEDURE

ITEM 13: ACCURACY OF THE LOAD CELL

DESCRIPTION OF TEST:

Determine the accuracy of the load cell in relation to known weights.

ACCEPTANCE CRITERIA:

The weight given by the load cell must be within ± 5% of the weight given by the kitchen scale.

REQUIRED MATERIALS:

1. Small kitchen scale.
2. Opened wine bottle.
3. 2 Identical wine glasses.

TESTING PROTOCOL:

1. Place the wine glass on the platform mounted to the load cell.
2. Zero out the load cell.
3. Manually pour a small (unspecified) amount of wine into the glass.
4. Record the weight of the wine given by the load cell.
5. Place an identical wine glass on the kitchen scale and zero out the scale.
6. Pour the wine from the first glass into the one on the kitchen scale, being careful not to spill any wine.
7. Record the weight of the wine given by the kitchen scale.

Pass / Fail

TEST PROCEDURE

ITEM 13: ACCURACY OF THE LOAD CELL

DATA:

Known Weight (g)	Load Cell Output (g)	Load Cell Pass/Fail (± 5%)
0	**0.93**	Pass
100	**99.47**	Pass
200	**198.00**	Pass
300	**299.35**	Pass
400	**403.52**	Pass
500	**499.24**	Pass
600	**600.59**	Pass
700	**699.13**	Pass

OBSERVATIONS:

The load cell is accurate to within 1 gram. The equation to convert the load cell raw output into grams is [(known weight)-334.67]/0.3552. This is based on a Load Cell Feedback curve that was produced when comparing the load cell output to the known weights.

Pass / Fail

TEST PROCEDURE

ITEM 14: AMOUNT OF WINE POURED

DESCRIPTION OF TEST:

The motor-load cell system will pour the correct amount of wine using a feedback loop.

ACCEPTANCE CRITERIA:

The weight poured by the machine must be within ± 5% of the selected target weight.

REQUIRED MATERIALS:

1. Small kitchen scale.
2. A full, opened wine bottle.
3. A wine glass.

TESTING PROTOCOL:

1. Place the wine glass on the kitchen scale and tare the scale.
2. Power on the machine.
3. Place the wine glass on the machine's wine glass plate.
4. Zero out the load cell *(performed by the pouring controller)*.
5. Command the machine to pour a selected volume of wine.
6. Transfer the wine glass to the kitchen scale, being careful not to spill any wine.
7. Record the weight of the wine given by the kitchen scale.
8. Perform steps 3-7 a total of five times for each of the three pour volumes.

Pass / Fail

TEST PROCEDURE

ITEM 14: AMOUNT OF WINE POURED

DATA:

Volume Desired	Volume Poured	Volume Pass/Fail (± 5%)	Volume Pass/Fail *(± 10%)*
5oz	5.0	Pass	Pass
5oz	5.0	Pass	Pass
5oz	5.4	**Fail**	Pass
5oz	4.9	Pass	Pass
5oz	4.7	**Fail**	Pass
4oz	4.4	**Fail**	Pass
4oz	4.2	Pass	Pass
4oz	4.5	**Fail**	**Fail**
4oz	3.8	Pass	Pass
4oz	4.1	Pass	Pass
2oz	2.1	Pass	Pass
2oz	2.2	**Fail**	Pass
2oz	1.9	Pass	Pass
2oz	2.2	**Fail**	Pass
2oz	1.8	**Fail**	Pass

OBSERVATIONS:

The pouring controller still has inaccuracies that prevent us from achieving repeatable error of 5% or less. However, the controller is able to pour within 10% error margins almost all of the time.

Pass / Fail

TEST PROCEDURE

ITEM 15: UI WORKS PROPERLY

DESCRIPTION OF TEST:

Run through complete operations of machine in different configurations and test for bugs.

ACCEPTANCE CRITERIA:

Proper functions are completed based on user input.

REQUIRED MATERIALS:

1. Foil sealed wine bottle
2. Wine Glass

TESTING PROTOCOL:

1. Run the program with inputs specified below.
2. Record if the specified functions, and only the specified functions, have run.

Pass / Fail

TEST PROCEDURE

ITEM 15: UI WORKS PROPERLY

DATA:

Test #	User Interface Pass/Fail	Notes
1	Pass	Foil on, cork on, tasting pour
2	Pass	Foil on, cork on, European pour
3	Pass	Foil on, cork on, American pour
4	Pass	Foil off, cork off, European pour
5	Pass	Foil on, cork off, European pour
6	Pass	Foil off, cork on, Tasting pour
7	Pass	5 consecutive American pours
8	Pass	Entering debug mode (hold tasting button)

OBSERVATIONS:

Note: For test 8, the debug mode is supposed to light the button up yellow, run the corkscrew in reverse, and then reboot the system as normal when first turning on. All the tests passed without problem.

When switching the controller off while operating, the machine will stop and hold current position.

Pass / Fail

TEST PROCEDURE

ITEM 16: EMERGENCY/STOP BUTTON WORKS

DESCRIPTION OF TEST:

Press the stop button in the middle of each operation.

ACCEPTANCE CRITERIA:

Machine stops its current action momentarily and then return to its neutral position.

REQUIRED MATERIALS:

1. Unopened wine bottle.

TESTING PROTOCOL:

1. Command the machine to run through the full procedure.
2. Press the stop button when the machine is in the middle of the foil cutting process.
3. Record reaction.
4. Repeat steps 2 and 3 for corkscrew function and pouring function.

Pass / Fail

TEST PROCEDURE

ITEM 16: EMERGENCY/STOP BUTTON WORKS

DATA:

Operation	Emergency/Stop Button Pass/Fail	Notes
Foil on, cork on, tasting pour	Pass	Stopped in the middle of pour, lowered the bottle, opened the foil cutter, and released the cork
Foil on, cork on, European pour	Pass	Stopped at start of cork removal, released foil, released cork
Foil on, cork off, tasting pour	Pass	Stopped during first rotation of tower, stopped it
Foil off, cork off, European pour	Pass	Stopped as the bottle was going up, bottle immediately reversed directions and went down
Foil on, cork on, American pour	Pass	Stopped in the middle of foil cutting, completed the pass it was on while opening foil cutter
In standby state	Pass	Pressed E-stop, then pressed pour button selection, no change, operations continued

OBSERVATIONS:

None

Pass / Fail

TEST PROCEDURE

ITEM 17: OPERATION TIME

DESCRIPTION OF TEST:

Run the machine through its longest operation.

ACCEPTANCE CRITERIA:

Longest operation is less than 90 seconds.

REQUIRED MATERIALS:

1. Stop watch.
2. Unopened bottle of wine.

TESTING PROTOCOL:

1. Place the bottle of wine into the gripper device and set the machine to cut the foil, remove the corkscrew.
2. Press the six ounce start button and start the timer.
3. When the bottle has returned to its starting position after it has poured the wine, stop the timer.
4. Record the time.

DATA:

Operation Time	Operation Time Pass/Fail
86 seconds	Pass

OBSERVATIONS:

Over 10 tests the average run time was 86 seconds with no runs over 88 seconds.

Pass / Fail

TEST PROCEDURE

ITEM 18: FITS THROUGH DOORWAY

DESCRIPTION OF TEST:

Carry fully assembled machine through a standard doorway.

ACCEPTANCE CRITERIA:

Machine fits through a standard doorway without coming into contact or damaging any aspect of the machine.

REQUIRED MATERIALS:

1. Standard doorway.

TESTING PROTOCOL:

1. Carry the machine through the doorway.
2. Simultaneously check for parts of the machine coming into contact with the frame of the door.

DATA:

Fit Pass/Fail
Pass

OBSERVATIONS:

The product's final footprint dimensions 21x18x31 inches. Since a standard doorway is 35 inches wide, and since the wine machine's length and width (21x18) are both less than this, the machine will fit through all doorways.

Pass / Fail

TEST PROCEDURE

ITEM 19: FITS IN CAR TRUNK OR BACK SEAT OF CAR

DESCRIPTION OF TEST:

Place machine in the back seat of small sedan. Place machine in trunk of small sedan.

ACCEPTANCE CRITERIA:

Machine fits in either the back seat or the trunk of a small sedan without coming into contact or damaging any aspect of the machine.

REQUIRED MATERIALS:

1. Small sedan.

TESTING PROTOCOL:

1. Slowly place the machine into the back seat of the sedan.
2. Simultaneously check for parts of the machine coming into contact with the sedan.
3. Repeat for the trunk of the sedan.

DATA:

Fit Pass/Fail
Pass: The machine's dimensions allow it to fit easily into the back seat. Fail: The machine will fit in the trunk but it must be laid down on its side when in the trunk. It is not meant to be transported in this manner. Overall: Pass because it will fit and is easily transportable.

Pass / Fail

TEST PROCEDURE

ITEM 20: WEIGHT

DESCRIPTION OF TEST:

Weigh the entire machine (without wine bottle and wine glass).

ACCEPTANCE CRITERIA:

Weighs less than 45 lbs.

REQUIRED MATERIALS:

1. Scale.

TESTING PROTOCOL:

1. Weigh the machine.
2. Record the weight.

DATA:

Weight	Weight Pass/Fail
32 LBS	PASS

Pass / Fail

TEST PROCEDURE

ITEM 21: LIQUID INGRESS

DESCRIPTION OF TEST:

Determine if the electrical base enclosure is liquid proof.

ACCEPTANCE CRITERIA:

No particular criteria. Results will be used to improve enclosure sealing.

REQUIRED MATERIALS:

1. Completed electrical base enclosure.
2. 10 ounces of water.
3. Stopwatch.
4. Towels.

TESTING PROTOCOL:

1. Place enclosure in wettable area.
2. Pour 10 ounces of water onto upper surface of the enclosure.
3. Set the timer for 1 minute.
4. When timer runs out, remove excess liquid from outer surfaces.
5. Inspect interior of enclosure for liquid ingress.

DATA:

Liquid Proof Pass/Fail	Notes
FAIL	This test was too severe to operate in a senior design project setting. Without time for a complete reorder and reassembly of all electronic components, this test would most likely damage our machine and would not be able to perform at expo. The acrylic shielding inside the electronics box and the multiple drainage areas are meant to clear *small* amounts of liquid spilled.

Pass / Fail

TEST PROCEDURE

ITEM 22: PULLING CORK THROUGH WAX SEAL

DESCRIPTION OF TEST:

Determine if corkscrew is able to pull the cork out through the wax sealed wine bottles.

ACCEPTANCE CRITERIA:

Cork completely removed.

REQUIRED MATERIALS:

1. Wax sealed wine bottle.

TESTING PROTOCOL:

1. Manually place corkscrew at center of cork.
2. Actuate electric corkscrew
3. Check for breakage of the cork.
4. Check for full removal of the cork.

DATA:

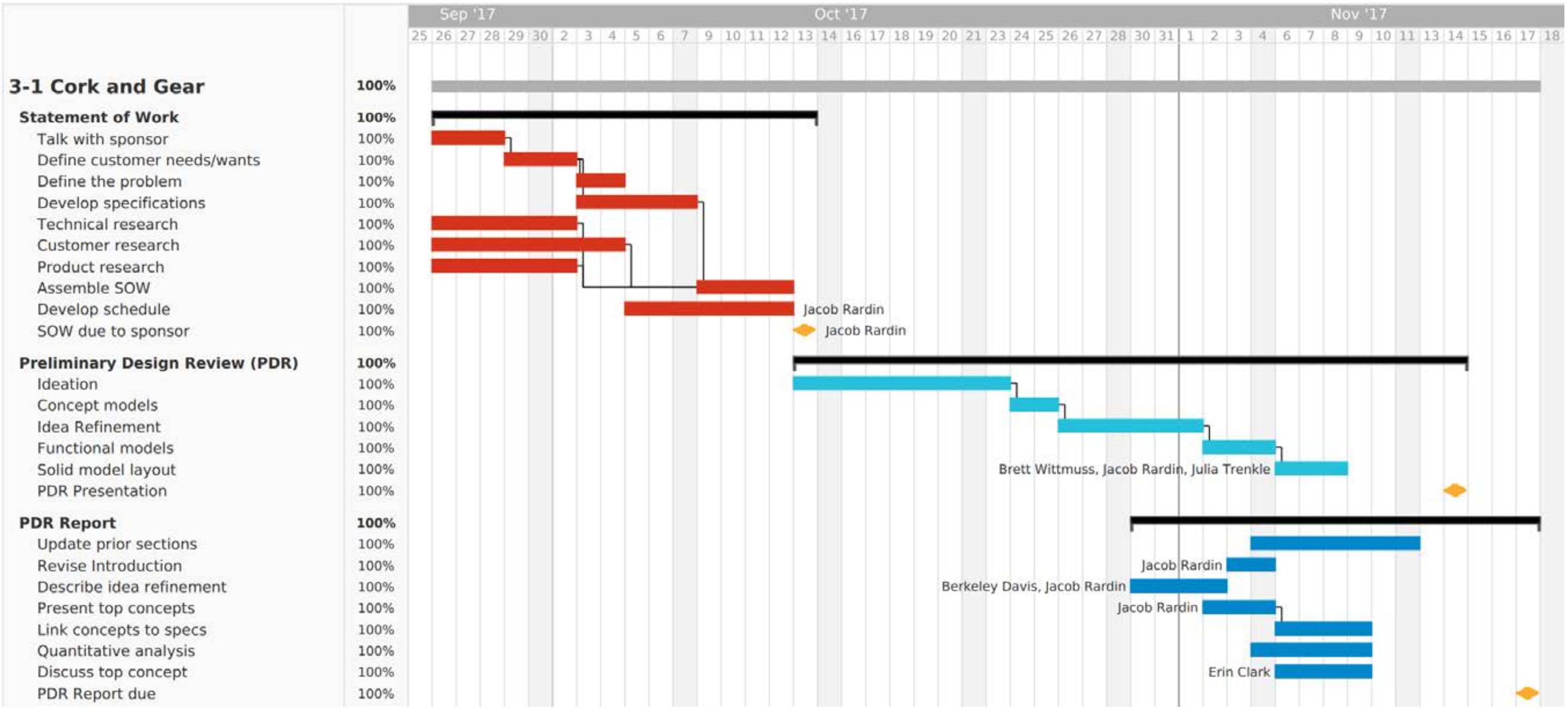
Liquid Proof Pass/Fail	Notes
FAIL	The cork failed to enter through the wax, then when more force was applied downward to get the screw to engage, it tore through the side, breaking the cork, and would not remove.

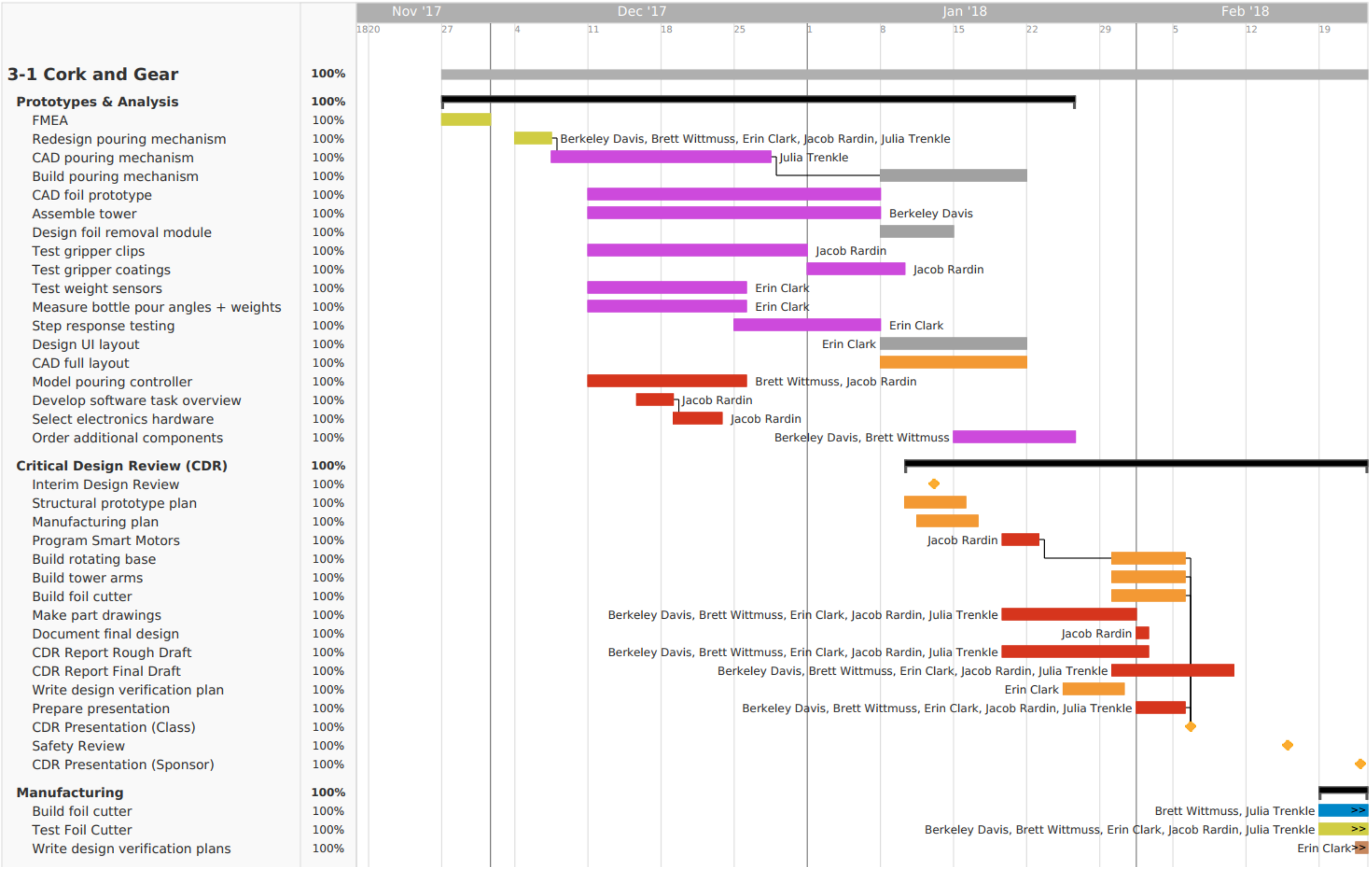
OBSERVATIONS:

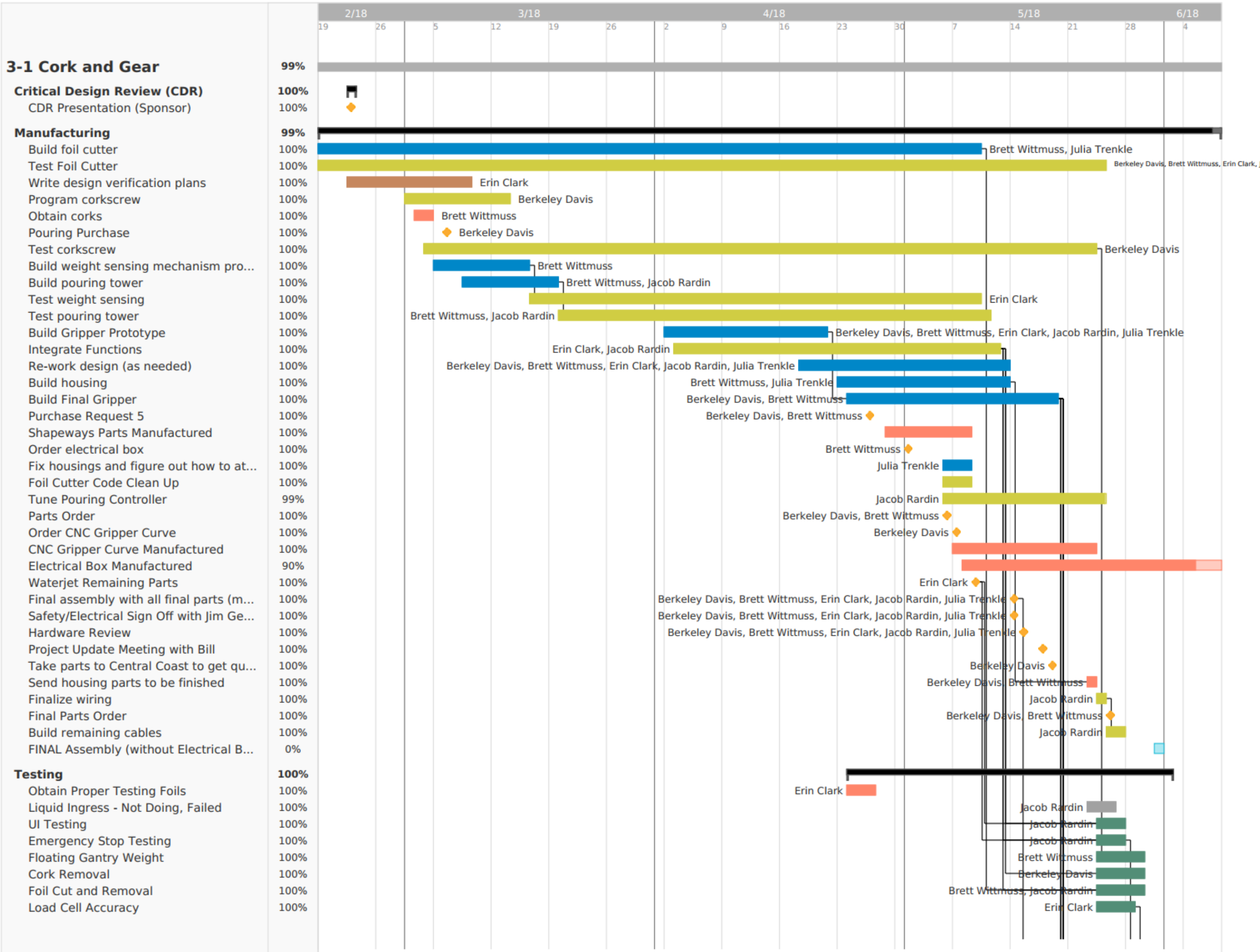
The wax seal on the bottle is very strong. Even though the corkscrew is very successful with the foiled bottles, it is not able to perform and supply enough power to drive the cork out. The cork was eventually removed after cutting off the top surface of the wax and using the cork remover like normal. The recommendation for wax sealed bottles is to cut off the top layer of wax before putting it into the machine.

Pass / Fail

APPENDIX L: GANTT CHARTS




Nov '17
Dec '17
Jan '18
Feb '18
18 20 27 4 11 18 25 1 8 15 22 29 5 12 19
3-1 Cork and Gear 100%
Prototypes & Analysis 100%
FMEA 100%
Redesign pouring mechanism 100%
CAD pouring mechanism 100%
Build pouring mechanism 100%
CAD foil prototype 100%
Assemble tower 100%
Design foil removal module 100%
Test gripper clips 100%
Test gripper coatings 100%
Test weight sensors 100%
Measure bottle pour angles + weights 100%
Step response testing 100%
Design UI layout 100%
CAD full layout 100%
Model pouring controller 100%
Develop software task overview 100%
Select electronics hardware 100%
Order additional components 100%
Critical Design Review (CDR) 100%
Interim Design Review 100%
Structural prototype plan 100%
Manufacturing plan 100%
Program Smart Motors 100%
Build rotating base 100%
Build tower arms 100%
Build foil cutter 100%
Make part drawings 100%
Document final design 100%
CDR Report Rough Draft 100%
CDR Report Final Draft 100%
Write design verification plan 100%
Prepare presentation 100%
CDR Presentation (Class) 100%
Safety Review 100%
CDR Presentation (Sponsor) 100%
Manufacturing 100%
Build foil cutter 100%
Test Foil Cutter 100%
Write design verification plans 100%
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Julia Trenkle
Berkeley Davis
Jacob Rardin
Jacob Rardin
Erin Clark
Erin Clark
Erin Clark
Erin Clark
Brett Wittmuss, Jacob Rardin
Jacob Rardin
Jacob Rardin
Berkeley Davis, Brett Wittmuss
Jacob Rardin
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Jacob Rardin
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Erin Clark
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Brett Wittmuss, Julia Trenkle
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Erin Clark


2/18
3/18
4/18
5/18
6/18
3-1 Cork and Gear 99%
Critical Design Review (CDR) 100%
CDR Presentation (Sponsor) 100%
Manufacturing 99%
Build foil cutter 100%
Test Foil Cutter 100%
Write design verification plans 100%
Program corkscrew 100%
Obtain corks 100%
Pouring Purchase 100%
Test corkscrew 100%
Build weight sensing mechanism pro... 100%
Build pouring tower 100%
Test weight sensing 100%
Test pouring tower 100%
Build Gripper Prototype 100%
Integrate Functions 100%
Re-work design (as needed) 100%
Build housing 100%
Build Final Gripper 100%
Purchase Request 5 100%
Shapeways Parts Manufactured 100%
Order electrical box 100%
Fix housings and figure out how to at... 100%
Foil Cutter Code Clean Up 100%
Tune Pouring Controller 99%
Parts Order 100%
Order CNC Gripper Curve 100%
CNC Gripper Curve Manufactured 100%
Electrical Box Manufactured 90%
Waterjet Remaining Parts 100%
Final assembly with all final parts (m... 100%
Safety/Electrical Sign Off with Jim Ge... 100%
Hardware Review 100%
Project Update Meeting with Bill 100%
Take parts to Central Coast to get qu... 100%
Send housing parts to be finished 100%
Finalize wiring 100%
Final Parts Order 100%
Build remaining cables 100%
FINAL Assembly (without Electrical B... 0%
Testing 100%
Obtain Proper Testing Foils 100%
Liquid Ingress - Not Doing, Failed 100%
UI Testing 100%
Emergency Stop Testing 100%
Floating Gantry Weight 100%
Cork Removal 100%
Foil Cut and Removal 100%
Load Cell Accuracy 100%
Brett Wittmuss, Julia Trenkle
Erin Clark
Berkeley Davis
Brett Wittmuss
Berkeley Davis
Berkeley Davis
Brett Wittmuss
Brett Wittmuss, Jacob Rardin
Erin Clark
Brett Wittmuss, Jacob Rardin
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Erin Clark, Jacob Rardin
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Brett Wittmuss, Julia Trenkle
Berkeley Davis, Brett Wittmuss
Berkeley Davis, Brett Wittmuss
Brett Wittmuss
Julia Trenkle
Jacob Rardin
Berkeley Davis, Brett Wittmuss
Berkeley Davis
Erin Clark
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Berkeley Davis, Brett Wittmuss, Erin Clark, Jacob Rardin, Julia Trenkle
Berkeley Davis
Berkeley Davis, Brett Wittmuss
Jacob Rardin
Berkeley Davis, Brett Wittmuss
Jacob Rardin
Erin Clark
Jacob Rardin
Jacob Rardin
Jacob Rardin
Brett Wittmuss
Berkeley Davis
Brett Wittmuss, Jacob Rardin
Erin Clark

APPENDIX M: BUDGET

Initial Budget	**$4,500**

Gripper Purchase Request			
Name	**Order Quantity**	**Unit Cost**	**Cost**
V-slot NEMA 17 linear actuator bundle 500mm black include motor	1	$139.05	$139.05
V-slot Gantry Set Universal Plate Xtreme solid V wheels	1	$43.55	$43.55
PQ12 Linear Actuator 20mm, 100:1, 12V, Potentiometer	2	$65.55	$131.10
0.78 Kg Micro Load Cell	1	$6.00	$6.00
Load Cell / Wheatstone Amplifier Shield (2ch	1	$19.95	$19.95
8mm diameter, 10N/2.2lb force	1	$75.00	$75.00
5A Cytron Servo Controller Shield	1	$18.75	$18.75
Dynamixal Smart Servo - Pouring	1	$305.90	$305.90
Dynamixal Smart Servo - Turntable	2	$39.95	$79.90
smart servo controller	1	$24.20	$24.20
arduino mega	1	$56.35	$56.35
turntable bearing	1	$10.71	$10.71
12" servo wire extender	8	$1.95	$15.60
power supply 12V-5A	1	$24.95	$24.95
Spring clip - large	2	$10.99	$21.98
Spring clip - small (pack of 3)	1	$4.47	$4.47
Grip pads (pack of 10)	1	$9.99	$9.99
Anti-slip spray coating	1	$15.98	$15.98
Total			$1,003.43
Remaining Budget			$3,496.57

Purchase Request 2			
Name	**Order Quantity**	**Unit Cost**	**Cost**
V slot Linear Rail - Black	2	$16.50	$33.00
90 degree angle bracket	4	$2.75	$11.00
m5 tee nut - 25 pack	2	$4.95	$9.90
L bracket	20	$1.00	$20.00
8mm M5 screw - 25 pack	1	$3.00	$3.00
12mm M5 screw - 25 pack	1	$3.25	$3.25
Scratch-Resistant Acrylic	2	$14.27	$28.54

Gikfun EasyDriver Shield Stepper Motor Driver V44 A3967 for Arduino EK1204	1	$5.98	$5.98
Total			$114.67
Remaining Budget			$3,381.90

Pouring Mechanism Purchase Request			
Name	**Order Quantity**	**Unit Cost**	**Cost**
L Bracket	20	$1.29	$25.80
Black Angle Corner Connector	10	$2.99	$29.90
aluminum bar	1	$3.33	$3.33
aluminum bar	1	$5.03	$5.03
thumb screw	2	$6.00	$12.00
aluminum rod	1	$1.99	$1.99
lock collar hinge	1	$117.21	$117.21
acrylic plate	1	$55.10	$55.10
8mm M5 low profile screw - 10 pack	1	$3.00	$3.00
M5 tee nuts - 10 pack	1	$2.99	$2.99
12mm M5 low profile screw - 10 pack	1	$1.49	$1.49
M5 thin hex nuts - 100 pack	1	$2.86	$2.86
M5 hex nuts - 100 pack	1	$9.85	$9.85
8mm M3 button head hex drive screw - 100 pack	1	$6.63	$6.63
14mm M3 button head hex drive screw - 50 pack	1	$12.75	$12.75
14mm M5 hex drive flat head screw - 100 pack	1	$7.83	$7.83
30mm M3 button head hex drive screw - 50 pack	1	$10.00	$10.00
M3 hex nuts	1	$5.39	$5.39
SN74LS241N Tri-State Buffer	3	$0.86	$2.58
22mm Metal Pushbutton	4	$22.00	$88.00
Micro Load Cell	4	$4.00	$16.00
Clear acrylic extruded tube	1	$39.00	$39.00
Total			$403.73
Remaining Budget			$2,978.17

Purchase Request 3			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Gantry plate	1	$38.99	$38.99
V-slot wheel	1	$6.99	$6.99
Black angle corner connectors	10	$2.99	$29.90
Drawer handles	2	$3.99	$7.98

Aluminum plates	1	$16.88	$16.88
Aluminum plates	1	$14.99	$14.99
Acrylic	1	$14.27	$14.27
Hinge	2	$8.60	$17.20
Fasteners	1	$9.63	$9.63
Nuts	1	$2.22	$2.22
Washers	1	$1.55	$1.55
Barrel jack, panel mount	1	$12.99	$12.99
Power supply	1	$28.98	$28.98
Dynamixel cable (cancelled due to backorder)	~~3~~	~~$4.90~~	~~$0.00~~
Toggle switches	4	$9.36	$37.44
Keylock switch	1	$18.99	$18.99
Screw terminal blocks	12	$0.74	$8.88
Dynamixel cable socket	3	$0.51	$1.53
Header socket	6	$2.32	$13.92
Capacitor	4	$2.13	$8.52
MP6500 Stepper Motor Driver Carrier, Potentiometer Control	3	$5.95	$17.85
VNH5019 Motor Driver Carrier	2	$24.95	$49.90
DC12V to 6V/3A Step Down Voltage Module	2	$9.51	$19.02
Resistor	8	$0.59	$4.72
Dynamixel cable plug	10	$0.35	$3.50
Dynamixel cable terminal	1	$5.40	$5.40
Total			$392.24
Remaining Budget			$2,585.93

Additional Costs not Recorded in PRs so far			
New dynamixel motor + linear servos	1	$491.10	$491.10
Returned linear servos			+$175.90
Shipping Costs (PR 1 - PR 3)			$222.06
Total			$537.26
Remaining Budget			$2,048.67

Purchase Request 4			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Aluminum plates	2	$26.14	$52.28
Handle	2	$9.33	$18.66
Linear Servos	2	$70.00	$140.00
Total			$210.94
Remaining Budget			$1,837.73

Purchase Request 5			
Name	Order Quantity	Unit Cost	Cost
Custom L brackets	1	$10.11	$12.05
Rubber Screw Caps	1	$3.89	$3.89
Large L Bracket	1	$11.99	$11.99
V-slot wheel	3	$6.99	$20.97
Gantry Plate	1	$38.99	$38.99
round bumper	1	$12.67	$12.67
m5 tee nut	3	$2.99	$8.97
m5 8mm nut	4	$1.39	$5.56
m5 8mm nut	4	$1.49	$5.96
L Brackets	20	$1.29	$25.80
tubing	1	$37.04	$37.04
Arm Housing	1	$16.42	$16.42
Housing Weight Standoff 20mm	4	$2.34	$9.36
Housing Weight Standoff 30mm	4	$2.77	$11.08
Housing Weight Standoff 35 mm	4	$2.80	$11.20
Housing Weight Standoff 40 mm	4	$2.68	$10.72
8 channel 5V relay	1	$9.59	$9.59
5mm screw terminal blocks	1	$8.63	$8.63
Jumper wires	1	$7.86	$7.86
1/4" PCB standoffs	15	$1.82	$27.30
2-56 3/16" machine screws	1	$5.74	$5.74
Lever limit switch	2	$8.88	$17.76
Motor Driver	2	$5.95	$11.90
Foil Cutter Housing tube	1	$37.24	$37.24
Tower Housing Metal Sheet.	4	$10.20	$40.80
Base Plate Metal Sheet	1	$68.90	$68.90
Total			$458.12
Remaining Budget			$1,379.61

Shipping Costs (PR 4 and on)	$149.39
Reimbursement Costs	$321.60
Remaining Budget	$908.62

Gripper Curve			
Name	Order Quantity	Unit Cost	Cost
Gripper curve - CNC	1	$145.00	$161.73
Total			$161.73
Remaining Budget			$746.89

4/21/2018			
Name	Order Quantity	Unit Cost	Cost
ACE Hardware (Main power wiring)		$17.36	$17.36
Total			$17.36
Remaining Budget			$729.53

5/10/2018			
Name	Order Quantity	Unit Cost	Cost
Aluminum M-F Threaded Hex Standoff, 6mm Hex, 30mm Long, M3 x 0.50 mm Thread (+ S/H)	4	$2.77	$18.23
Total			$18.23
Remaining Budget			$711.30

5/13/2018			
Name	Order Quantity	Unit Cost	Cost
Neck Clamp Rubber Insert			$152.19
Neck Clamp Rubber Insert Shipping			$25.58
Total			$177.77
Remaining Budget			$533.53

5/16/2018			
Name	Order Quantity	Unit Cost	Cost
Welding of Housing			$40.00
Standoffs			$36.59
Arduino Mega			$29.50
Electrical Box			$582.66
Purchase 5/16/18 (RobotShop, OpenBuilds)			$59.02
Total			$747.77
Remaining Budget			-$214.24

5/17/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Sponsor Approved Budget Increase			+$475.00
Remaining Budget			$260.76

5/21/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Thumb Screws	4	$4.23	$16.92
Brushes	2	$36.18	$72.36
Thumb Screw Shipping			$7.58
Brushes Shipping			$11.88
Total			$108.74
Remaining Budget			$152.02

5/22/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
RobotShop Dynamixel Servo Return Refund			+$260.00
Remaining Budget			$412.02

5/23/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Powder Coating			$80.00
Remaining Budget			$332.02

5/25/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Electric Corkscrew	2	$19.99	$39.98
Foil Cutter	2	$6.99	$13.98
Caution Label	1	$10.13	$10.13
Rubber Sheet	1	$5.35	$5.35
Rust Remover	1	$6.45	$6.45
Nylon Locknut	1	$4.41	$4.41
Cushioning Washer	1	$7.70	$7.70
Fuse	1	$9.29	$9.29
Microfiber Polishing Wipe	1	$3.68	$3.68
Fuse Holder	2	$5.08	$10.16

Target Tax			$46.27
Amazon Shipping			$13.98
McMaster Shipping			$12.27
Total			$183.65
Remaining Budget			$40.61

5/30/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Home Depot			$25.00
Total			$25.00
Remaining Budget			$ 15.61

6/7/2018			
Name	**Order Quantity**	**Unit Cost**	**Cost**
Amazon			$6.49
Protocase Discount for Late Delivery			+$291.33
Total			-$284.84
Remaining Budget			$300.45
Total Remaining Budget (Current)			**$300.45**

Cork and Gear Operator's Manual

Safety Information

Always follow basic safety precautions when using this product to reduce risk of injury from sharp blades, pinch points, or electric shock:

- Read and understand the setup instructions in this operator's manual.
- Use only a grounded electrical outlet when connecting the unit to a power source. If you do not know whether the outlet is grounded, check with a qualified electrician.
- Observe all warnings and instructions labeled on the product.
- Unplug this product from wall outlets before cleaning.
- Do not install or use this product near water or when you are wet.
- Install the product securely on a stable surface.
- Use only the listed power adapter.
- Install the product in a protected location where no one can step on or trip over the power cord, and where the power cord will not be damaged.
- If the product does not operate normally, immediately press the emergency stop button and see the troubleshooting information. There are no operator serviceable parts inside. Refer servicing to qualified service personnel.
- Use in a well-ventilated area.
- Keep children away from this device.
- Take care if manually removing foils and/or corks in their respective moving tool arms.
- Keep hands away from device while it is operating.
- Ensure the device is turned off, locked out, and that foil cutting blades and corkscrew are fully retracted when transporting.

Warnings

Always follow basic precautions and instructions when using this product to reduce risk of breaking the device or causing injury to yourself or others:

- Do not forcefully press on the weight sensor or place on it anything but a wine glass. Any pressure larger than that of its intended use will break the sensor.

- Transport the machine right side up at all times. The floating gantry slides when not upright. Take care when transporting and cover all powder coated edges on supporting surfaces to avoid damage to the surface treatment.
- Do not place hands inside foil cutter mechanism, cork remover mechanism, rotating tower, or between the pouring tower and gripping backbone while the device is operating. These areas are potential pinch points or have open machinery.
- If the device malfunctions or an emergency occurs, press the Emergency Stop button located on the front panel of the electronics box.

TABLE OF CONTENTS

1 WELCOME

This reference manual is provided for basic operation of the wine opening device and basic trouble shooting. For issues beyond basic troubleshooting, video references will be provided for further detail on how the device was assembled.

1.1 WINE OPENER PARTS

This section reviews the components of the wine opening device and how they will be referred to throughout the manual.

1.1.1 BASIC COMPONENTS

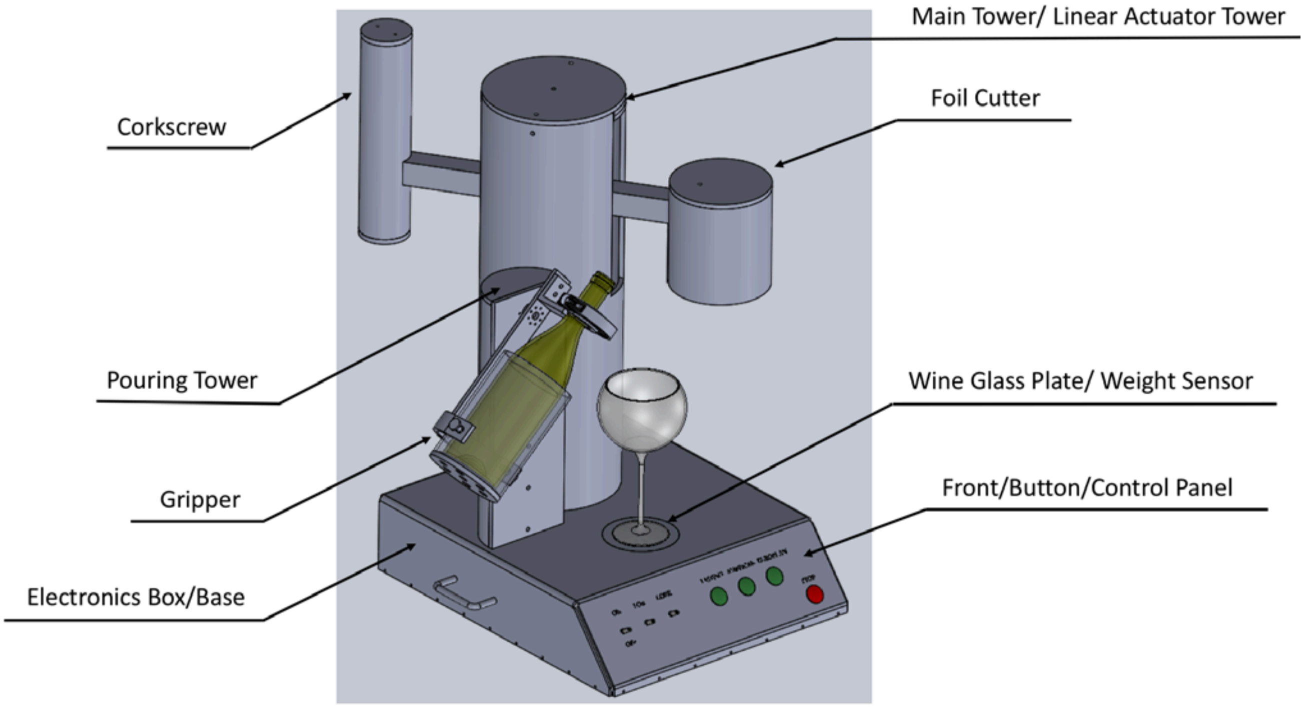


Figure 1.1. Basic Components as they are referred to in this manual.

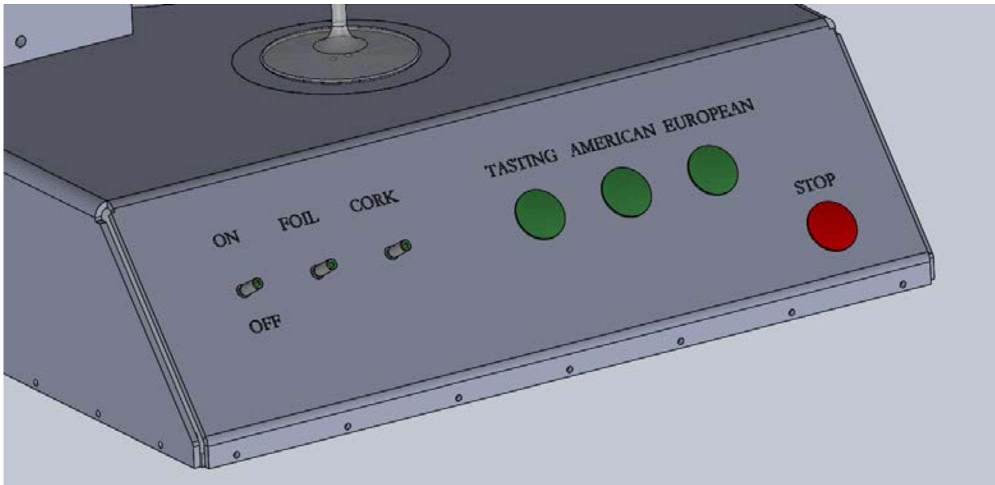


Figure 1.2. Front/Button/Control Panel

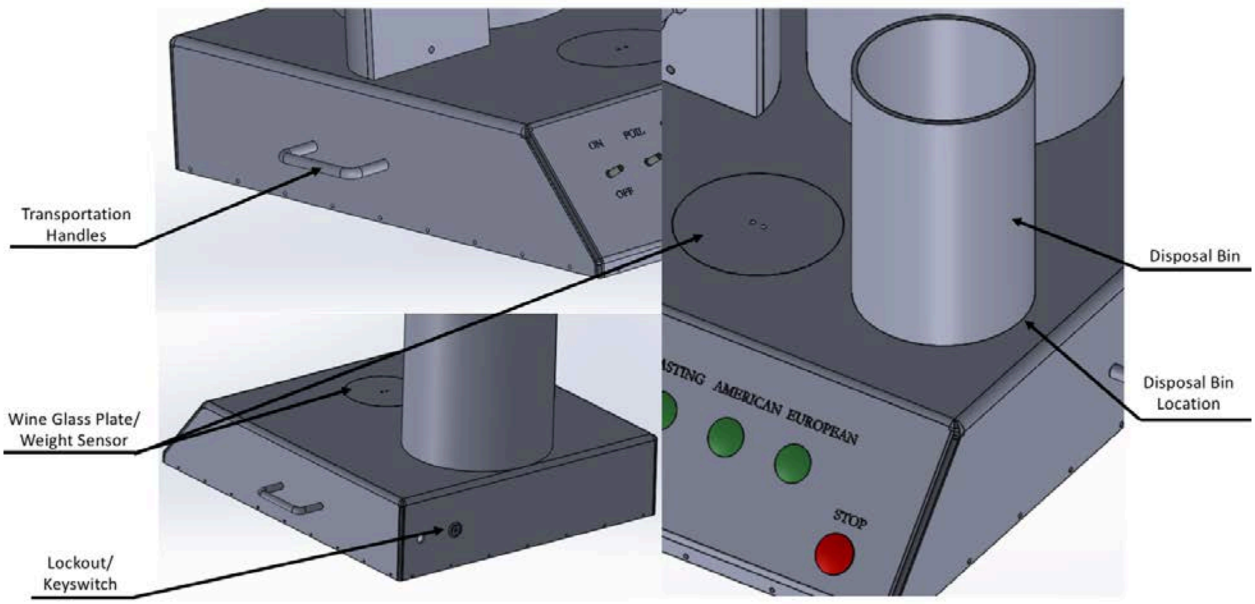


Figure 1.3. Electronics Box Specifics

1.1.2 MAIN TOWER

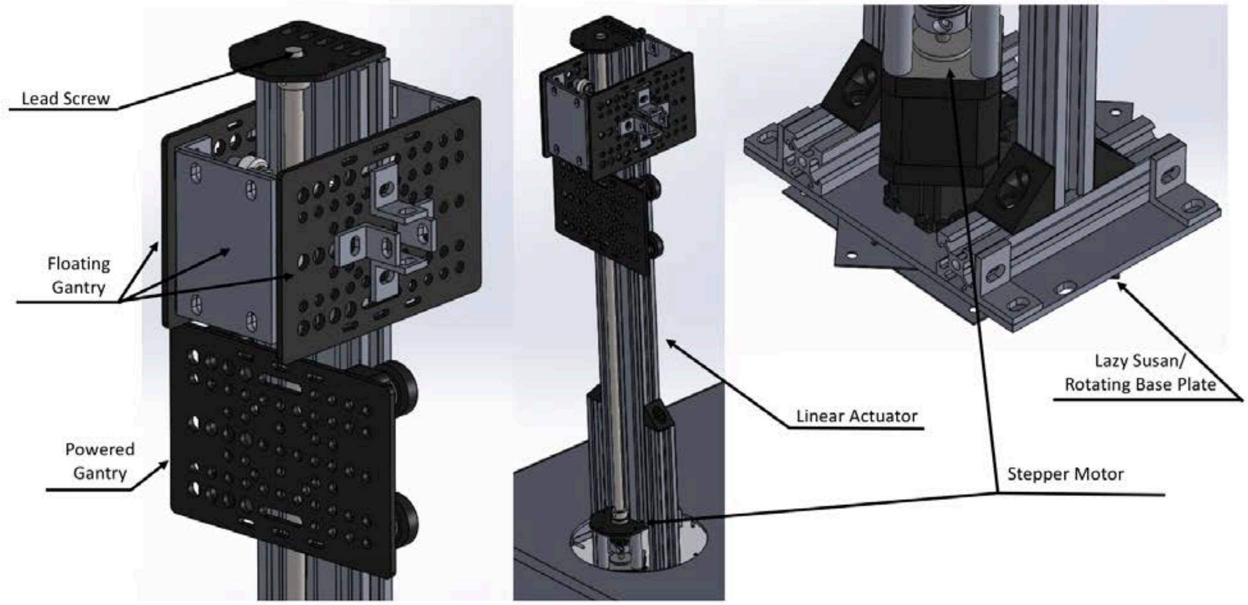


Figure 1.4. Main Tower/Linear Actuator Tower Components

1.1.3 POURING TOWER AND GRIPPER

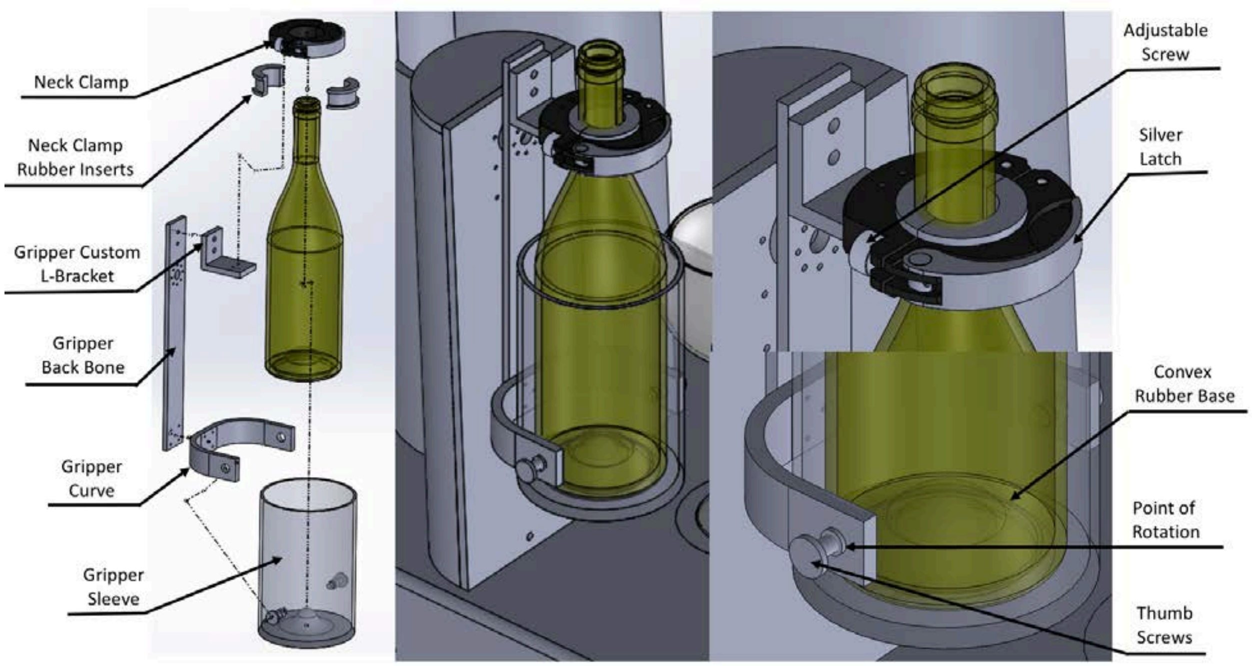


Figure 1.5. Pouring Tower and Gripper Specific Components

1.1.4 Foil Cutter Tool

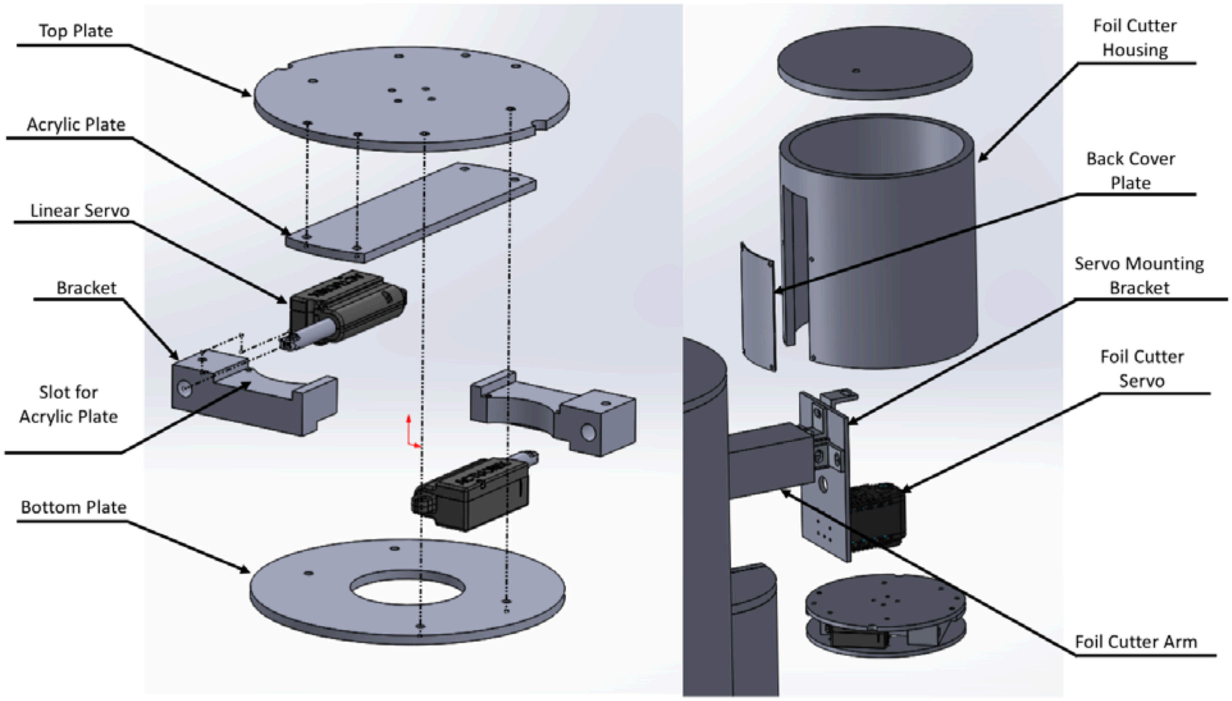


Figure 1.6. Foil Cutter Tool Components

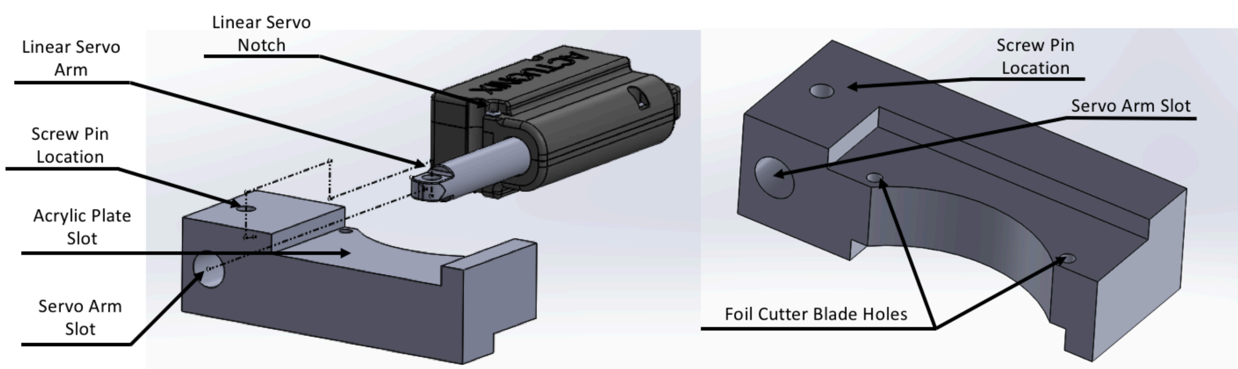


Figure 1.7. Foil Cutter Bracket and Linear Servo Components

1.1.5 Corkscrew Tool

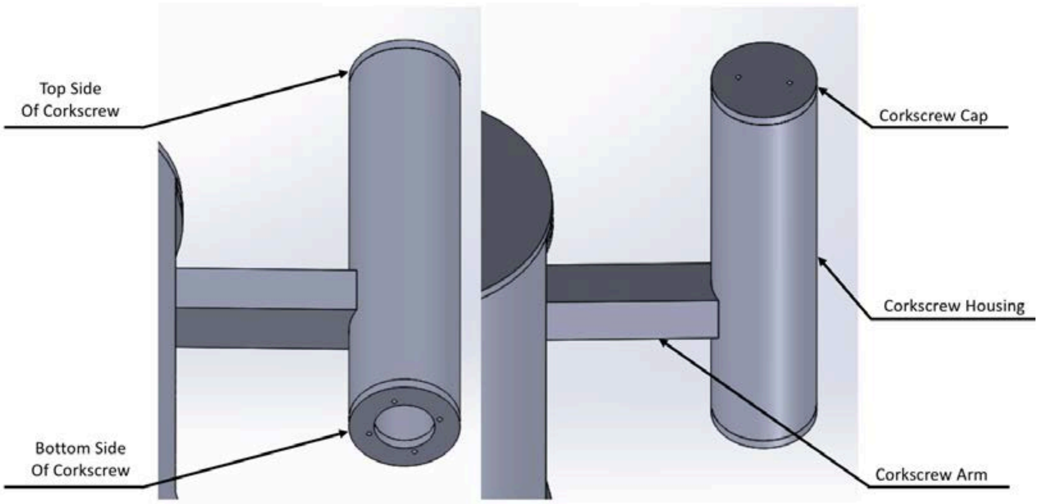


Figure 1.8. Corkscrew Tool Components

1.1.6 Wine Glass Plate/Weight Sensor

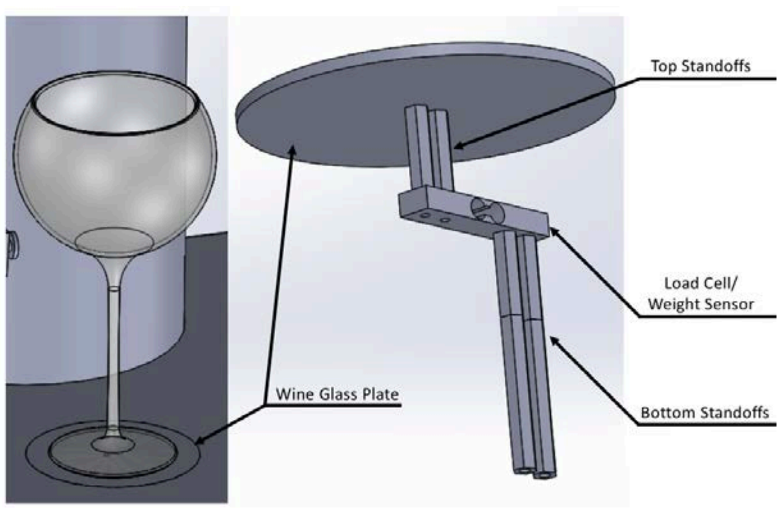


Figure 1.9. Wine Glass Plate/Weight Sensor Components

1.1.7 Electronics Base

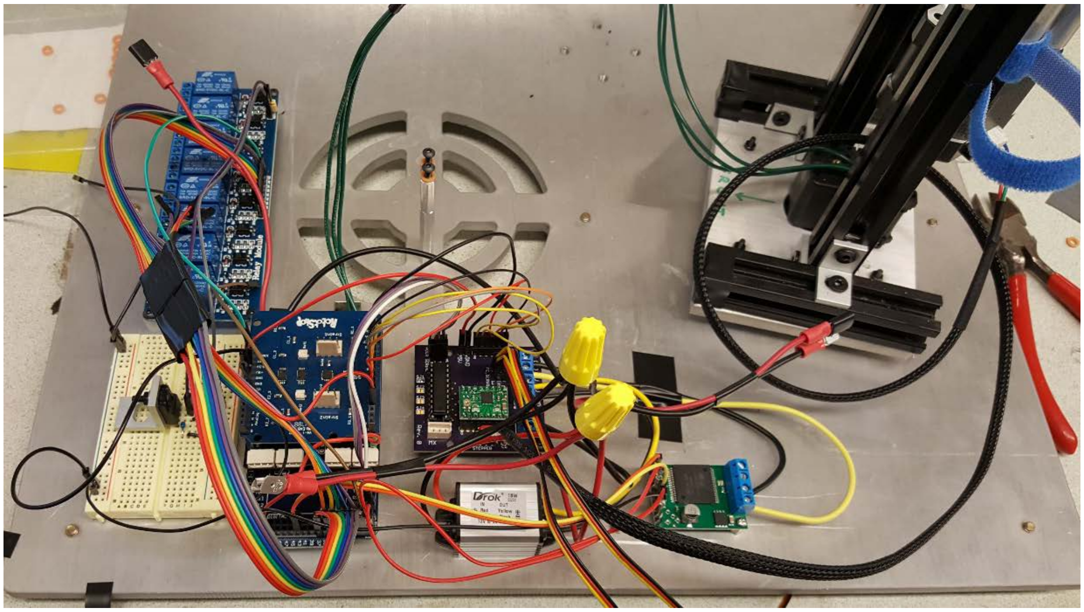


Figure 1.10. Electronic components mounted to the base plate.

1.2 BATTERY INFORMATION

Due to weight concerns and the difficulty of incorporating an internal battery into the project, we are recommending an external battery pack that can be plugged in to the device. We are recommending the Goal Zero Yeti 150 Portable Power Station, Goal Zero Yeti 400, and Anker Powerhouse in that order. These packs were chosen for the ability to power the device for at least one full day and have a convenient 12V DC output. The Yeti's were chosen before the Anker model due to the included barrel jack output, meaning a male to male barrel jack adapter is all that is needed to run it. The Powerhouse has an overall sleeker design but would require an adapter (either from a car 12V DC or run through a typical wall plug). The Yeti models are also heavier than the Anker due to the use of lead acid batteries instead of Lithium (the 400 model Yeti has a lithium option). The 150 is recommended for lowest price but the 400 model and the powerhouse are larger and would be able to power several days of the device running or power other devices (phones, laptops, etc.) in addition to the device. Additionally, a goal zero portable solar charger could be added if you wanted to power the device using solar power. This would allow the device to be run for long periods of time in areas that have minimal access to power where it would be set up. Links to these devices are provided below:

Goal Zero Yeti 150 Portable Power Station

Goal Zero Yeti 400

Anker Powerhouse

Please consult an electrician before installing any of these batteries with the wine opener. Additionally, be sure to obtain instructions on how to set up the battery in locations where the wine opener may be transported, as these instructions will not be provided in this manual.

2 GETTING STARTED

2.1 RUNNING THE DEVICE WHEN PLUGGED INTO AN OUTLET.

The following procedure should be followed when powering and setting up the wine opening device at the winery or other location where a standard outlet is accessible.

1. Plug the power supply into the nearest outlet, being sure not to string the cord in a location where it will create a tripping hazard.
2. Insert the key into the key switch on the back side of the electronics base box and turn the key 90 degrees clockwise to the "on" position as shown in Figure 2.1.

Figure 2.1. Keyswitch.

3. Open the neck clamp first by rotating the silver latch away from the clamp (Figure 2.2 -2). Next, loosen the adjustable screw and slide it out of the slot in the clasp (Figure 2.2-3) to release the clamp (Figure 2.2-4).

Figure 2.2. Opening the neck clamp.

4. Loosen the thumb screws on the sides of the clear bottle sleeve until the screws sit flush with the inside of the sleeve (Figure 2.3).

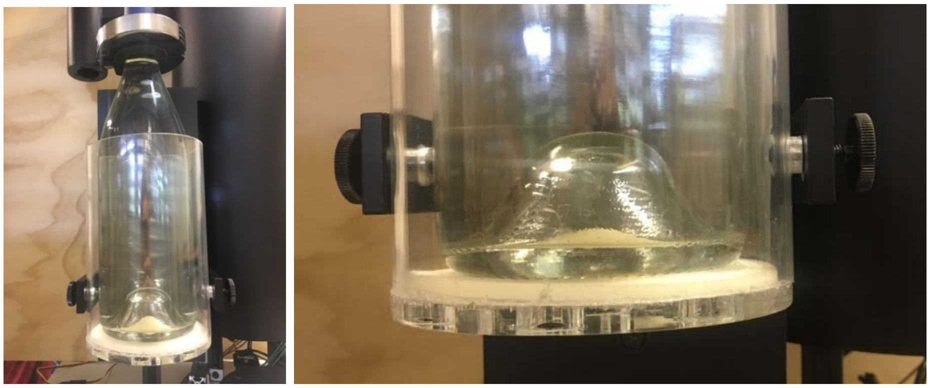


Figure 2.3. Loosening the thumb screws.

5. Rotate the gripper sleeve away from the gripper backbone by gently pulling the sleeve towards the front of the electronics base box until it sits around 45 degrees, or is open enough to place the bottle into the sleeve (Figure 2.4).

Figure 2.4. Inserting the bottle into the gripper sleeve.

6. Rotate the bottle and gripper sleeve back to its vertical position and be sure that the bottle is pressed firmly into the convex rubber base and that the bottle is centered against it.
7. Close the neck clamp around the bottle neck and secure it by sliding the adjustable screw back into the slot of the clasp (Figure 2.5). Be sure that the silver latch is rotated as far away from the bottle as possible before rotating the adjustable screw clock wise. Slowly begin to close the silver latch. If no resistance is felt when closing the latch, rotate it back, and rotate the screw a quarter of a turn clock wise before closing the latch again. Repeat this process until just a slight amount of resistance is felt when closing the latch. If a lot of resistance is felt when closing the latch, return the latch back to its open position and rotate the screw about and eighth of a turn counter clockwise before closing the latch again.

<ins>Note:</ins> Closing the latch should not be difficult. However, if closing the latch with a bottle in place is as easy as closing the latch without a bottle in place, there is not enough resistance for the clamp to be fully effective. Slight resistance should be felt, but not so much that it is difficult to close the latch.

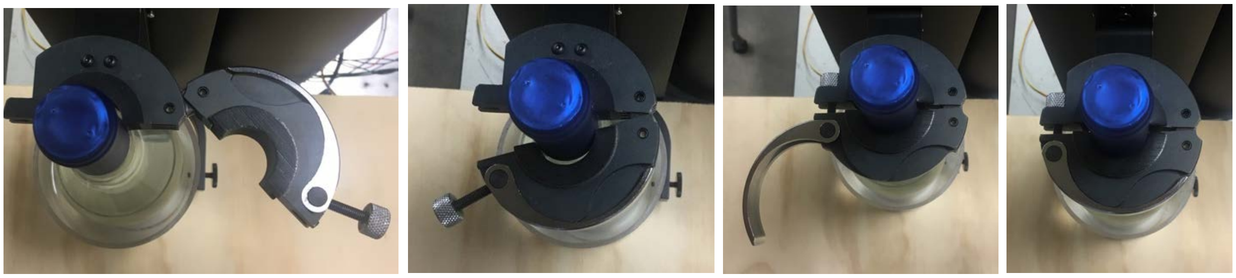


Figure 2.5. Securing the bottle with the neck clamp.

8. Rotate both of the thumb screws in the clockwise direction simultaneously in order to keep the bottle centered within the clear bottle sleeve (Figure 2.6).

Figure 2.6. Securing the bottle with the thumb screws.

9. Flip the power toggle to the "On" position on the front panel (Figure 2.7). The pour size buttons will blink red to allow the machine to power on and initialize itself. The buttons will remain red when the machine is ready. You are now ready to operate the wine opener.

Note: If the red LED on the end of the toggle switch does not light up, please reference the troubleshooting section (5.1) of this manual.

Figure 2.7. Turning the wine opener on.

2.1.1 Basic Operation

This section describes the basic operation of the novel wine opener. Section 2.2 describes how to successfully open and pour an unopened bottle. Section 2.3 describes how to pour a bottle that has already been opened.

2.2 UNOPENED BOTTLE

This section describes how to open and pour an unopened bottle of wine. Section 2.2.1 describes how to open a bottle covered in foil, and Section 2.2.2 describes how to open a bottle sealed with wax.

2.2.1 Foil Sealed Bottle

Follow the procedure below to successfully open and pour a wine bottle sealed with foil:

1. Flip both the cork toggle switch and the foil toggle switch to the "On" position on the front panel (Figure 2.8). The red LED on the end of each toggle switch should light up.

Note: If the LED on either of these toggles does not turn on, please see Section 5.1 for troubleshooting techniques.

Figure 2.8. Opening a bottle sealed with foil.

2. Place a wine glass gently on the center of the weight sensor indicated by the glass location circle (Figure 2.9). Be sure not to place additional weight or pressure on the sensor, as it will break with too much force.


Figure 2.9. Placing the wine glass on the weight sensor.

3. Selecting Pour Size: Please note that each of the pour size buttons also function as the start button for that size of pour. The LED for the selected pour size will turn from red to green while the other LEDs will turn off, and the machine will begin to open the bottle before pouring.
    - Do not touch the glass after the machine has been started.
    - If something is to not function as described in this manual, press the emergency stop button immediately and refer to the troubleshooting section (5) of this manual.

4. Wait for the bottle to return to its vertical position, and for the machine to drop the foil cap and cork into the disposal bin before removing the glass from the weight sensor. When all of the pour size LEDs turn back to red, the machine will be ready to pour another glass.

2.3 OPENED BOTTLE

This section describes how to pour an opened bottle of wine.

1. Flip the cork and foil toggle to the "Off" position on the front panel. The red LED on the end of each toggle switch should be off.
2. Place a wine glass gently on the center of the weight sensor indicated by the glass location circle (see Figure 2.9). Be sure not to place additional weight or pressure on the sensor, as it will break with too much force.
3. Selecting Pour Size: Please note that each of the pour size buttons also function as the start button for that size of pour. The LED for the selected pour size will turn from red to green while the other LEDs will turn off, and the machine will begin to open the bottle before pouring.
    - Do not touch the glass after the machine has been started.
    - If something is to not function as described in this manual, press the emergency stop button immediately and refer to the troubleshooting section (5) of this manual.
4. Wait for the bottle to return to its vertical position. When all of the pour size LEDs turn back to red, the machine will be ready to pour another glass.

3 TRANSPORTATION

The following should always be taken into careful consideration when transporting the wine opening device:

- Ensure the gripper sleeve remains secure and cannot rotate.
- Move the neck clamp to its closed position to keep it from swinging open.
- Ensure the linear actuator and pouring towers remain secure and cannot rotate.
- Do not place anything on the top surface of the electronics base.
- Always set the wine opener on a flat surface and do not tilt it or lean it up against other objects.
- Use two people to transport the wine opener when possible, and always use the transportation handles on the sides of the base.
- If a single person is transporting the wine opener, pick the wine opener up from the back side using the handles on the sides of the base.

The wine opener has drawer handles on the sides of the base for convenient gripping locations. The handles are placed lower than the center of gravity to avoid damage to the machine and to allow for easier balance when transporting. Note that the machine should only be transported by these handles and possibly (when using two people), an accompanying hand on the base. This is to ensure that there is no damage to the machine when carrying it.

4 MAINTENANCE

4.1 CLEANING

The following should always be taken into careful consideration when cleaning the wine opening device:

- Clean up any spills immediately to prevent leakage into the electronics box.
- Take care not to press on the wine glass plate.
- Never leave a wine bottle in the gripper overnight, as this will cause unnecessary bending on the backbone of the gripper.

4.1.1 GENERAL SPILLS

The following should be done immediately if the device spills any amount of wine outside of the glass:

1. Gently wipe down the wine glass plate and the surrounding area. Do not use very much force on the wine glass plate, as it will break.
2. Use a soft, lightly damped cloth to wipe down the neck clamp.
3. Spray the neck clamp with the rust resistant spray provided to keep the clamp from rusting.

4.1.2 SPILLS INTO THE GRIPPER

If wine spills into the gripper sleeve:

1. Remove the bottle from the gripper sleeve.
2. Remove the convex rubber base from the gripper sleeve by pushing up through one of the drainage holes in the bottom of the gripper.
3. Wipe down the inside and outside of the gripper sleeve, including the area below the gripper where wine may have fallen.
4. Wipe the convex rubber base with a damp cloth and dry it off before placing it back in the sleeve. Be sure that the flat side of the base is facing downwards, and the contoured side is facing up.

4.1.3 ON A DAILY BASIS

The following should be done at the end of a day when the wine opener has been used:

1. Wipe down the top surface area of the electronics base box, being careful not to use too much force on the weight sensor.
2. Wipe down the next clamp and spray the neck clamp with the rust resistant spray provided to keep the clamp from rusting.
3. Use the microfiber cloth with warm, soapy water to wipe down the external surfaces of the wine opener.
4. If wine has spilled into the electronics base box by seeping past the wine glass plate at any point in the day, it will have fallen through to the surface on which the wine opener is sitting.

Place the wine opener on a separate, flat, surface before cleaning the original surface and returning the wine opener to its original spot.

5. Empty the disposal bin.

4.1.4 On a Monthly Basis

The following should be done on a monthly basis (or after the machine has been run many times):

1. Apply a light coating of bearing grease (white lithium or bicycle bearing grease) to the tower turntable bearing (Figure 4.1) and between the pouring motor spacers and pouring tower housing (Figure 4.2).
    - Refer to "Electronics Box Disassembly" videos for instructions removing the electronics base.
    - Refer to "Pouring Motor Disassembly" videos for instructions on accessing the pouring motor spacers.

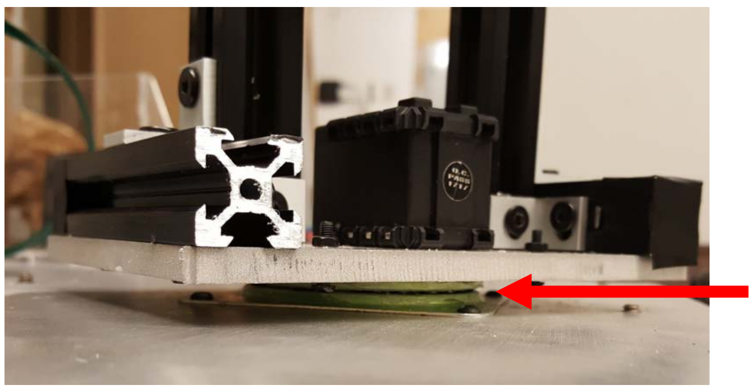


Figure 4.1 Turntable Bearing

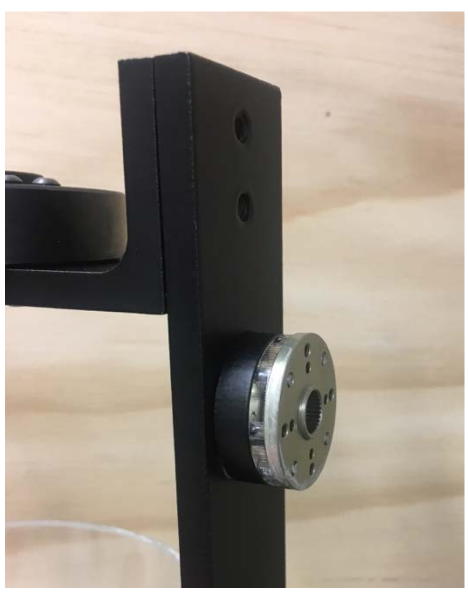


Figure 4.2 Pouring Motor Spacers

4.2 REPLACING WORN PARTS

The following procedures describe how to safely replace worn parts on the wine opening device. Some of these instructions may require knowledge of basic hardware and electrical systems; please do not attempt to replace parts until reading through all of these instructions. Seek professional help if you do not have the necessary knowledge.

4.2.1 REPLACING THE CORKSCREW

What you will need:

a) 2mm hex wrench

b) Replacement Corkscrew

1. Start by removing the four screws on the bottom side of the corkscrew housing using the hex wrench (Figure 4.3). Take the corkscrew housing cap off by removing the two screws on the top, revealing the corkscrew and its connecting wires (Figure 4.4).

Figure 4.3. Four screws on bottom side of corkscrew housing.

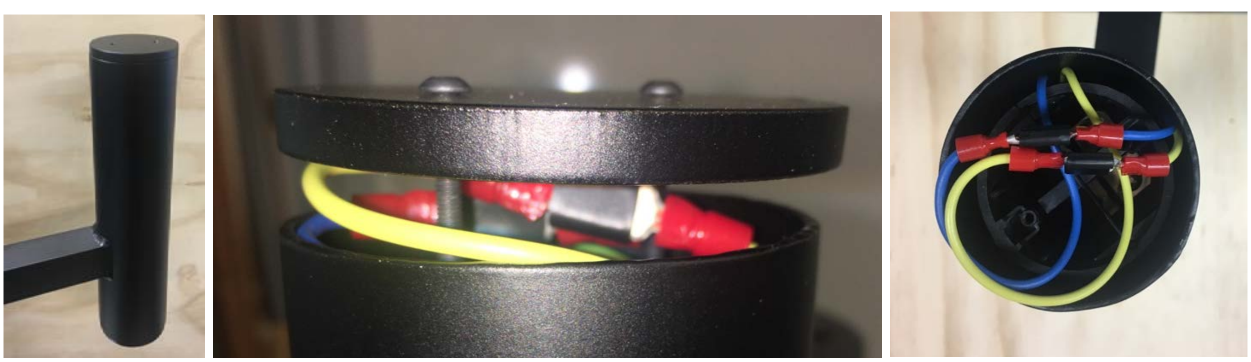


Figure 4.4. Two screws on top of corkscrew housing, revealing the wiring.

2. Disconnect the wiring to the corkscrew before removing the corkscrew from its housing. Connect the wires of the new corkscrew. If the wire colors on the new corkscrew are black and yellow, black will go to the blue wire in the housing, and yellow will go to the yellow wire.

If there are no more prewired corkscrews, the commercially produced Houdini electric corkscrew will need to be modified to fit the wine opening system. These instructions should be followed carefully in order to ensure the corkscrew is modified correctly. An exploded view of the internal components is shown in Figure 4.5 for reference, and to indicate what the terms used throughout this section are referring to.

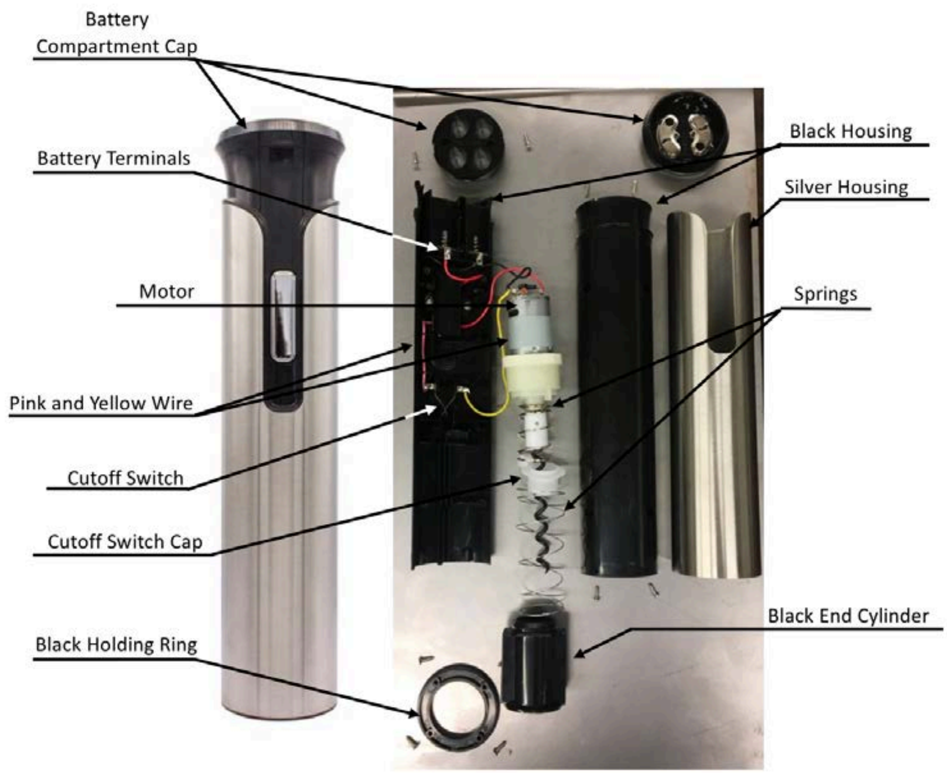


Figure 4.5. Exploded view of electrical components in the corkscrew.

What you will need:

a) Philips #1 screwdriver
b) Safety glasses
c) Wire clippers
d) Wire strippers
e) Black or Blue 18-gauge stranded wire (approximately 8 inches long)
f) Yellow 18-gauge stranded wire (approximately 8 inches long)
g) Soldering iron and solder
h) Two ½-1 inch length pieces of heat shrink tubing (or electrical tape)
i) Heat gun
j) 1N400X diode (1N4001 or 1N4004 are suitable)
k) Drill with 3/16" drill bit
l) Two 22-16 gauge (red) quick-disconnect terminals

m) Quick disconnect crimp tool

n) M3 tap

1. Remove the four screws on the bottom side of the corkscrew housing before taking the black holding ring off of the corkscrew. (The holding ring will not be put back on the corkscrew and these four screws will be replaced by those already on the wine opener.)
2. Pull the silver housing off to reveal the entirety of the black housing (the silver housing will not be put back on the corkscrew).
3. Detach the cap to the battery compartment by rotating it counter clockwise and pulling up (The battery compartment cap will not be put back on the corkscrew.
4. Remove the two screws that lay beneath the battery cap (These screws will be replaced by those already on the wine opener).
5. Unscrew the four screws on the side of the corkscrew and split the two halves of the black casing to reveal the internal electrical components (keep these four screws).

Note: There are springs within the corkscrew that may fall out when the two halves are split. Be sure not to lose these springs.

6. Remove the black end cylinder, the two springs, and the plastic white cutoff switch cap and set these aside for later (Figure 4.6).

Figure 4.6. Two springs, cutoff switch cap, and black end cylinder.

7. Lift the attached corkscrew and motor away from the black housing (Figure 4.7).

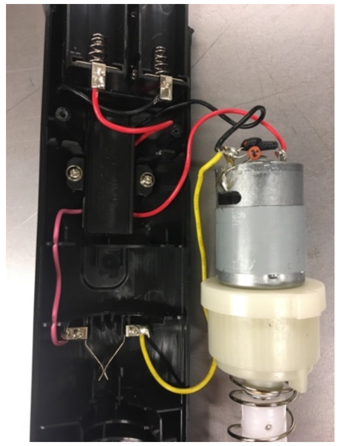


Figure 4.7. Corkscrew motor lifted away from casing.

8. Slide the battery terminals out of their respective slots and clip the wires as far away from the terminals as possible (the clippings no longer attached can be thrown away) (Figure 4.8).

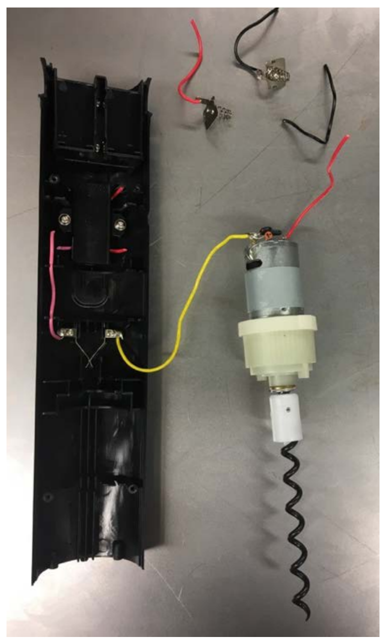


Figure 4.8. Corkscrew battery terminals removed, and internal wires clipped.

9. Clip the black wire attached to the motor as close to the motor as close as possible without affecting the yellow wire next to it. Clip the red wire attached to the motor as far away from the motor as possible. Clip the pink wire as far away from the cutoff switch as possible. **Leave the yellow wire as it is.**
10. Strip the long end of the yellow and pink wires, and one end each of the black/blue wire and yellow wire to ¼ inch.
11. Solder the black or blue stranded wire to the pink wire.
12. Solder the yellow stranded wire to the red wire.

13. Place the heat shrink over the connections made in steps 11 and 12 and use the heat gun to shrink them down (Figure 4.9).

Figure 4.9. Corkscrew heat shrink connections.

14. Use the hand drill to drill a hole in the side of the black corkscrew casing in the location shown in Figure 4.10.

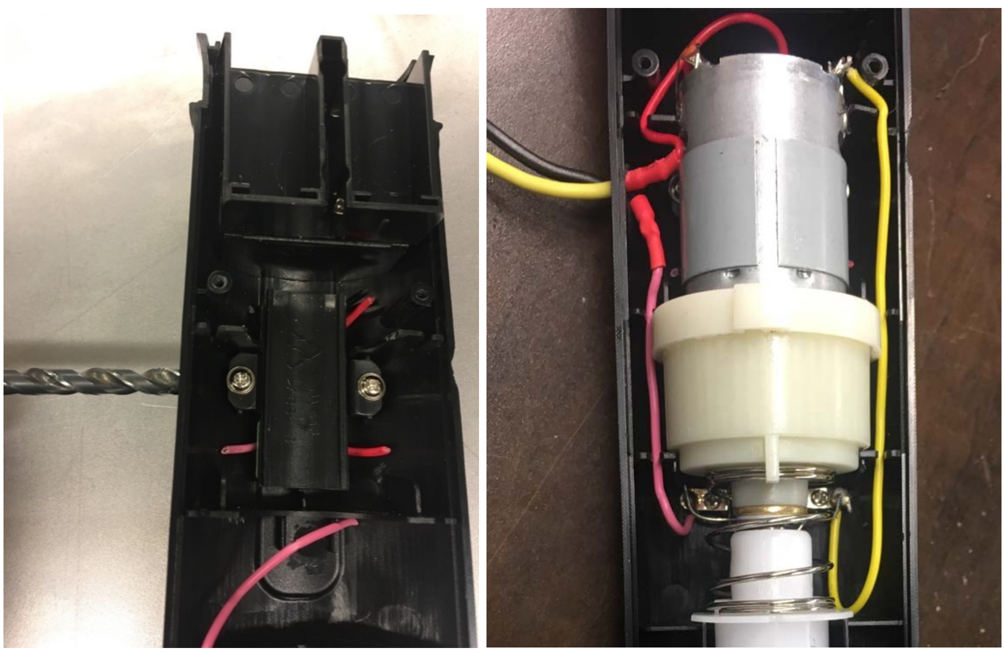


Figure 4.10. Hole drilled into the side of the corkscrew.

15. Solder the diode to the cutoff switch connections that hold the pink and yellow wires. The cathode (white band) on the diode should be facing the yellow wire (Figure 4.11).

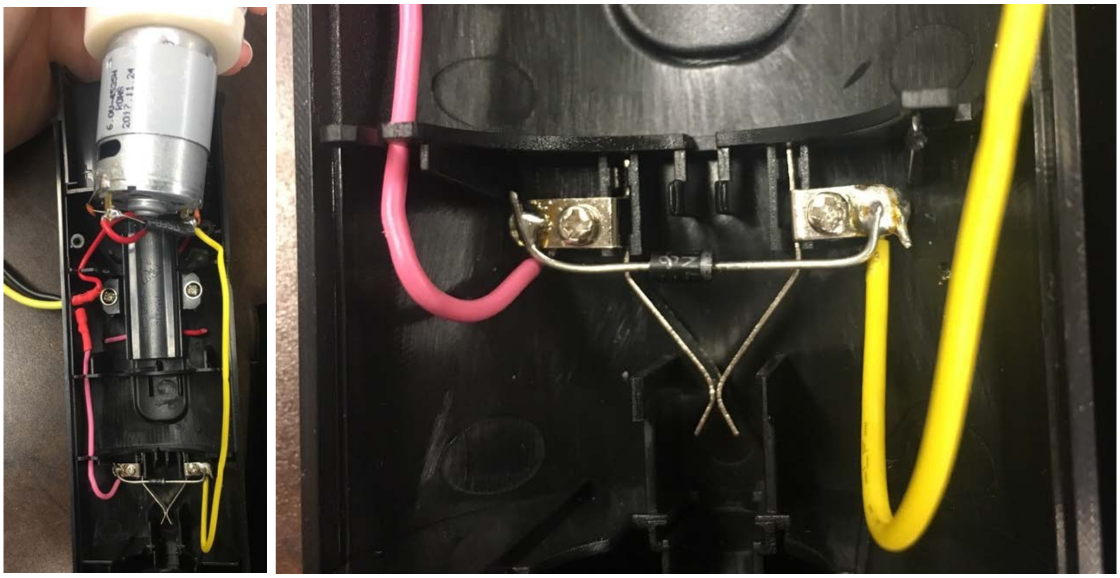


Figure 4.11. Fly back diode connected to cutoff switch terminals in corkscrew.

16. Route the black or blue and yellow stranded wires through the hole drilled in the side of the corkscrew, being sure to secure all internal wires down into the casing and out of the way (Figure 4.12).

Figure 4.12. Stranded wires routed through the drilled hole in the corkscrew casing.

17. Replace the plastic white cutoff switch cap, the two springs, and the black end cylinder before securing the two halves of the black casing back together with the four screws on the side.

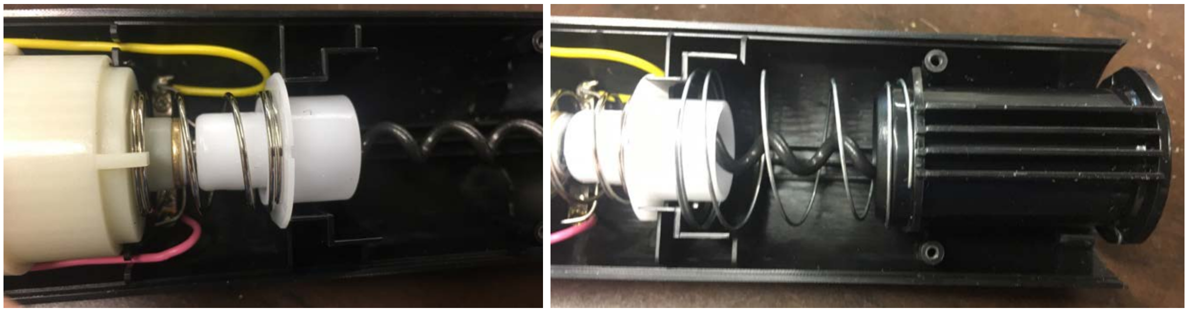


Figure 4.13. Replacing the cutoff switch cap, two springs, and black end cylinder.

18. Attach the female quick disconnect terminals to the black or blue and yellow wires that were routed to the outside of the black corkscrew casing using the crimp tool (Figure 4.14). Be sure that the quick disconnect terminals are tight enough by gently pulling on the wires and verifying that they do not come out.

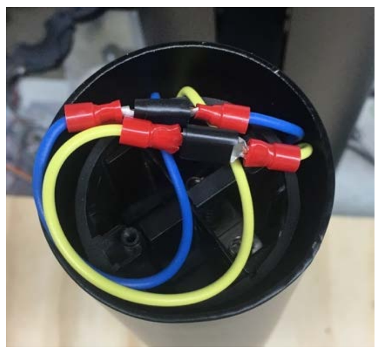


Figure 4.14. Female quick disconnect terminals attached to wires routed from corkscrew.

19. Use the M3 tap to re-tap the four holes on the bottom side of the corkscrew and the 2 holes at the battery compartment side.
20. The corkscrew should now be ready to place into the wine opener (Figure 4.15). Please see the beginning of this section for instructions on how to place the new corkscrew into the opener.

Figure 4.15. Completed modified corkscrew.

4.2.2 Replacing the Foil Cutting Blades

What you will need:

a) Philips #1 screwdriver

b) Two serrated replacement blades

1. Start by removing the four screws on the back cover plate of the foil cutter housing. Once the cover plate has been removed, loosen the screw on the top of the foil cutter housing shown in Figure 4.16.

Figure 4.16. Removing back cover plate of foil cutter housing.

2. Carefully remove the housing by lifting it straight up (Figure 4.17).

<u>Note:</u> There are various wires under this housing that have the potential to get caught on the housing, so remove it slowly.

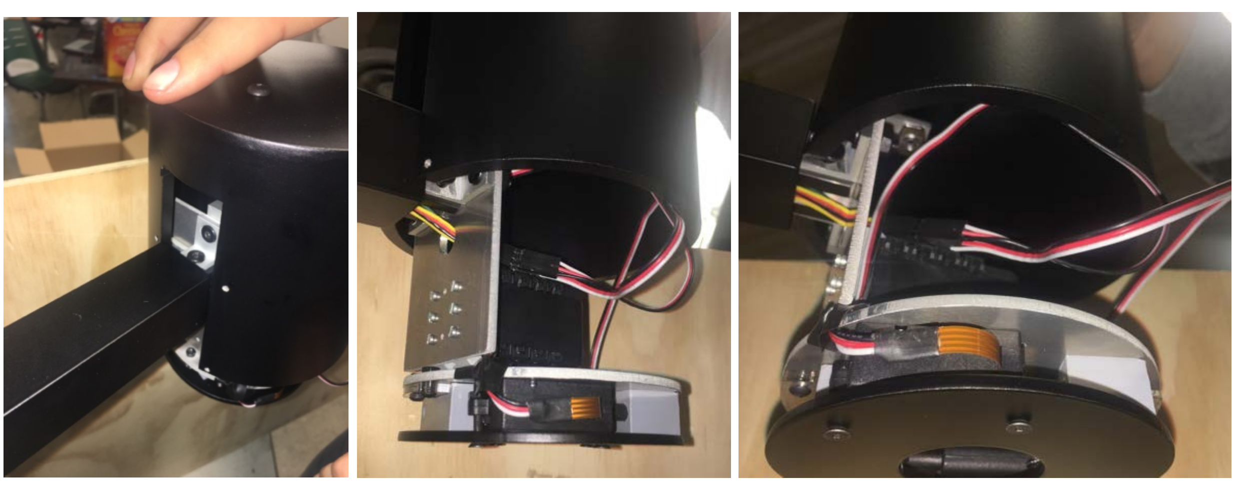


Figure 4.17. Removing foil cutter housing.

3. Remove the two nuts from the top foil cutter plate as indicated in Figure 4.18, and slide the screws out from the bottom. This should release the bottom foil cutter plate from the top one.

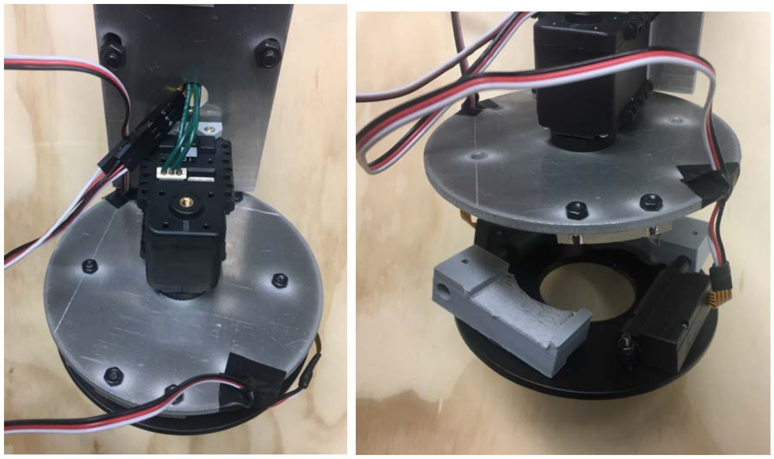


Figure 4.18. Release bottom foil cutter plate from bottom.

4. Leave the wires connected as they are and rotate the brackets away from the center of the plate (Figure 4.19).

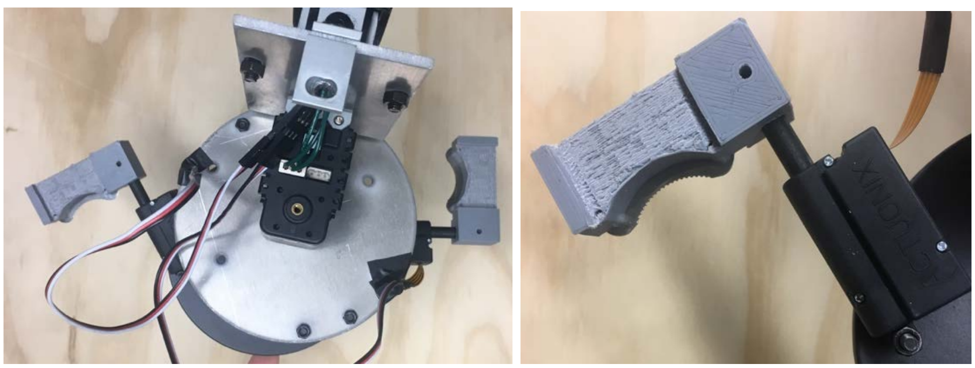


Figure 4.19. Rotate foil cutter brackets away from center.

5. Unscrew the two screws on each of the brackets to remove the blades. Replace the old blades with the new ones and the screw them back on to the brackets.
6. Rotate the brackets back towards the center of the foil cutter (Figure 4.20).

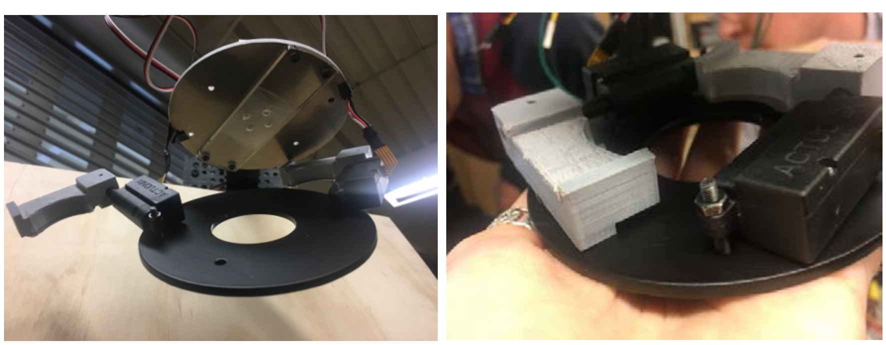


Figure 4.20. Rotate the brackets toward the center of the foil cutter.

7. Align the slots on the top of the brackets with the clear, thin acrylic plate attached to the top plate of the foil cutter (Figure 4.21).

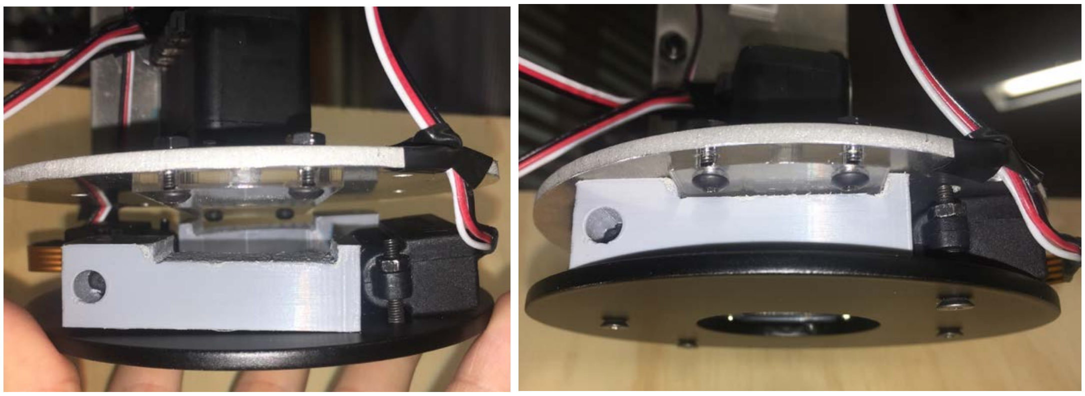


Figure 4.21. Align the slot of the brackets with the clear acrylic plate.

8. Replace the two screws that were taken out and fasten them with the nuts. Be sure that the screws line up with the small notch in the linear servos, so as to keep the servos in place (Figure 4.22).

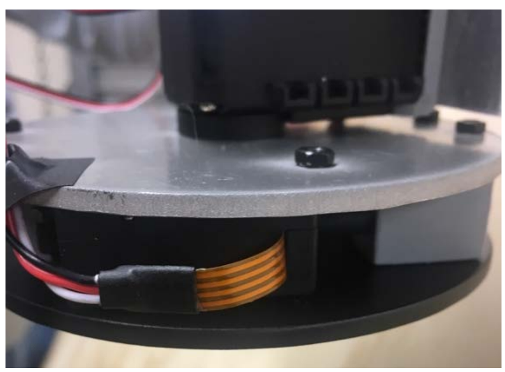


Figure 4.22. Attach the bottom and top plates of the foil cutter with the two screws and nuts.

9. Carefully slide the foil cutter housing back over the foil cutter, making sure that all of the wires are sitting just above the top plate. Fasten the single screw on the top of the housing to the foil cutter.
10. Attach the cover plate to the back of the foil cutter housing.

4.2.3 Replacing the Load Cell

If it has been determined that the load cell is broken, the following steps should be taken to replace it. In order to follow these steps, you will first have to remove the electronics base in order to unplug the load cell from the Arduino.

- See "Electronics Box Disassembly" videos for instructions on removing the electronics box.

What you will need:

a) 2mm hex wrench

b) New 0.78 kg micro load cell

Instructions:

1. Remove the two screws on top of the wine glass plate shown in Figure 4.23.

Figure 4.23. Remove the two screws on top of the wine glass plate.

2. Lift the wine glass plate off of the load cell (Figure 4.24).

Figure 4.24. Wine glass plate removed from load cell.

3. Note the orientation of the load cell (Figure 4.25) before removing the two screws attaching the load cell to the standoffs that sit on the bottom of the electronics base.

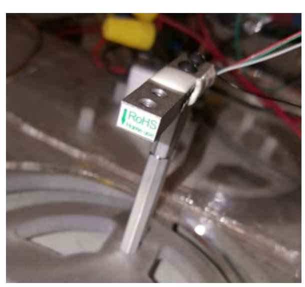


Figure 4.25. Load cell orientation.

4. Remove the two smaller standoffs from the old load cell and place them on to the new load cell.

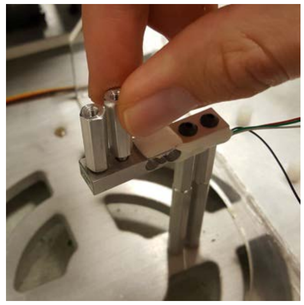


Figure 4.26. Remove top two standoffs from the old load cell and place on the new load cell.

5. Secure the new load cell to the standoffs sitting on the bottom of the electronics base.

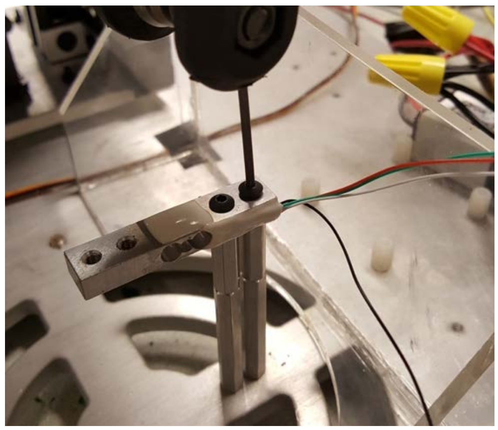


Figure 4.27.Remove the old load cell from the bottom standoffs and secure the new one.

6. Place the wine glass plate back on to the smaller standoffs on the top side of the load cell and secure it with the two screws on top of the plate.

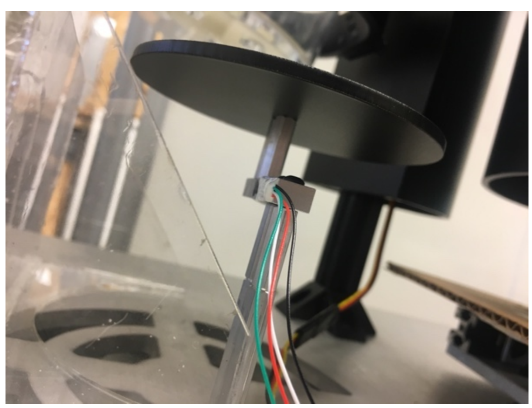


Figure 4.28. Place wine glass plate back onto top standoffs.

7. Be sure to reconnect the new load cell to the Arduino before placing the electronics box back onto the wine opener.

5 TROUBLESHOOTING

Note: If you have pressed the emergency stop button, you must switch the wine opener off and back on (via the main key switch in back or the on/off toggle on the front) to reset the Arduino microcontroller.

The following sections are set up to help you figure out what problem the wine opener is having, and how to go about fixing it. The first six sections are split up into the problems that you may come across and are followed by the potential causes of those issues. The potential causes are listed in the order in which they should be checked and the description for how each issue can be checked is provided in section seven. Some of the issues refer to a video description of how to fix the issue instead of being explained here in this document.

Instructions involving wire voltage and wire current inspection are written assuming the user has experience with electronics and experience using a multimeter. It is advised that professional help is sought for issues that require looking through the electronics.

5.1 WINE OPENER NOT TURNING ON

5.1.1 Buttons and/or Toggle Switches do not Light Up

Potential Causes:

1. Ensure the lockout key has been turned.
2. Ensure the wine pouring device is plugged in to its appropriate power source.
   - Plug the power cable completely into the power source. Make sure that the connection to the device is capable of supplying 12 volts and at least 8 amps. The provided power adapter converts U.S standard 120V mains power to 12 Volts. Check that the power cable adapter block is plugged in at both ends.
3. If running the machine off of the battery, ensure that the battery is charged.
   - Charge the battery. If the battery is dead, replace the battery.

5.1.2 Buttons and/or Toggle Switches Light Up but do not Work

Potential Causes:

1. The wire connection from power to the Arduino may have been disrupted. (5.7.1)
2. The Arduino is broken. (5.7.2)

5.2 POUR VOLUME ISSUES

5.2.1 Too Much Wine

Potential Causes:

1. The load cell is broken. (5.7.3)
2. The pouring motor is not responding correctly. (5.7.4)

3. The load cell is not calibrated correctly. (5.7.5)

5.2.2 Too Little Wine

Potential Causes:

1. The pouring motor is not responding correctly. (5.7.4)
2. The load cell may not be zeroing out when the pour size is selected. (5.7.6)
3. The load cell is not calibrated correctly. (5.7.5)
4. The motor driver chip may be broken. (5.7.8)

5.2.3 No Wine at all or Bottle not Rotating

Potential Causes:

1. The wine opener may think the bottle is empty.
    - The controller maintains a counter of how much volume it thinks is remaining. This counter is reset when the controller is turned on, and whenever the foil and cork routines are run (i.e. when a bottle is opened).
    - Turn the controller off and back on using the power toggle on the control panel. Be sure to wait 5-10 seconds before continuing operation.
2. The pouring motor wires may be disconnected. (5.7.7)
3. The load cell may not be zeroing out when the pour size is selected. (5.7.6)
4. The motor driver chip may be broken. (5.7.8)
5. The pouring motor may be broken. (5.7.9)

5.3 FOIL CUTTER ISSUES

5.3.1 Foil Not Fully Cut

1. One or more linear servos is not working. (5.7.10)
2. The foil cutter is not rotating. (5.7.12)
3. The blades are too dull.
    - Replace the foil cutting blades. Please see Section 4.2.2.
4. The linear servos are not squeezing tightly enough. (5.7.11)

5.3.2 Foil is cut but not being removed

1. The stepper motor is not working. (5.7.13)

5.4 CORK REMOVAL ISSUES

5.4.1 Corkscrew Caught in Cork

1. Corkscrew has been stalled. (5.7.14)

5.4.2 Cork only Partially Removed

1. Corkscrew did not run for long enough. (5.7.15)

5.4.3 The Cork Ripped or Crumbled

1. An older bottle was used.
    - If the cork ripped, the machine can be run again to try to get the second half out.
    - The machine was not intended to remove bottles with corks that will easily crumble. Please refrain from using bottles in which the corks are likely to crumble.

5.4.4 Cork Caught in Corkscrew

1. Corkscrew does not eject cork. (5.7.16)

5.5 MAIN TOWER ISSUES

5.5.1 Tower is not Centering Tools Properly

1. The rotating base is not well-lubricated. (5.7.17)
2. The setpoints are not set correctly for centering. (5.7.18)

5.5.2 Tower is not Rotating

1. The servo control did not have long enough to initialize.
    a. Always wait 5-10 seconds after switching the machine before operation.
2. The rotating base is not well-lubricated. (5.7.17)
3. The rotational servo may be broken. (5.7.19)

5.5.3 Tower not lifting tools high enough

1. The stepper motor may have too much friction. (5.7.20)
2. The tower was not reset between operations. (5.7.21)
3. The stepper motor may be broken. (5.7.13)

5.6 UI NOT WORKING

5.6.1 Button LED's Do Not Work

1. A connection from the Arduino to the control panel has been disconnected. (5.7.22)
2. The 12-volt power wiring may be disconnected. (5.7.23)

5.6.2 Toggle LED's Do Not Work

1. The wiring between the main power may have broken. (5.7.23)
2. The LED may be burned out.

5.6.3 Bottle Operations Take Place When They Should Not

1. The switch may be disconnected. (5.7.23)

2. The switch may be shorted to ground. (5.7.24)

5.6.4 Bottle Operations Do Not Take Place When They Should

1. The switch may be shorted to power. (5.7.25)
2. The relay may not be powered. (5.7.26)
3. The relay may be broken. (5.7.27)

5.6.5 Device Enters Emergency Stop State When Button is Not Pressed

1. The switch may be shorted to ground. (5.7.24)

5.7 CHECKING THE ISSUE

5.7.1 Power to Arduino Disrupted

1. Check that the lockout key on the back side of the electrical box has been turned.
2. Remove the electrical box and check that all wires are fully plugged into the Arduino.
3. Check that the internal fuse is intact. If not, check for electrical shorts within the electrical enclosure, and make sure that all motors can move freely and are clear of jams.
4. If the problem persists, check the voltage across all of the wires connecting to the Arduino with a multimeter. If 0V is read across a wire:
   - The connection is incomplete and the wire needs to be better secured, or
   - The wire is faulty and needs to be replaced.
     - See "Electronics Box Disassembly" videos for instructions on electrical box removal.

5.7.2 Arduino is Broken

1. If the Arduino is being supplied with 12V either through the Vin pin or the barrel jack, but the "ON" LED by the reset button does not come on, then the Arduino is broken.
2. Remove the electrical box and replace the Arduino, taking care to replace all connected wires to the same pins as the original Arduino.
   - See "Electronics Box Disassembly" videos for instructions on the electrical box removal.

5.7.3 Load Cell is Broken

Run a test pour on the machine without a bottle in the gripper and without a glass on the wine glass plate. Use the American size pour for this test. Be sure to turn the foil and cork toggles off.

While the gripper is tilted at an angle, press down gently on the wine glass plate for two seconds and then release.

Observe the reaction of the pouring motor.

- If the pouring motor decreases its tilt angle when you press on the plate, and then increases its tilt angle when you let go, the problem is not that the load cell is broken.
- If the pouring motor steadily increases its tilt angle before returning to its vertical position as you press on the wine glass plate, the load cell will need to be replaced. Please see section 4.2.3 for instructions on replacing the load cell.

5.7.4 POURING MOTOR NOT RESPONDING CORRECTLY

1. Please see Section 6.3 for adjusting the controller for the pouring motor in the code.

5.7.5 LOAD CELL NOT CALIBRATED

1. See the Section 6, 'Programming Guide', for instructions on how to change the pouring calibration constants. If adjusting these values does not change the pour volume, the load calibration is not the issue.
   - See "Electronics Box Disassembly" videos for instructions on electrical box removal.

5.7.6 LOAD CELL NOT ZEROING

1. Be sure that the wine glass is not being touched during or after the pour size selection. The load cell zeroes itself at this time and will account for any extra pressure placed onto the wine glass plate.
2. Turn the controller off and on again using the power on/off toggle. Wait 5-10 seconds for initialization before continued operation. (The pouring controller will occasionally accumulate error after several pours.)
3. If problem persists, remove the electrical box and connect to the Arduino. Check that the pouring controller is calling the "zero_LoadCell" function at the start of the pour.
   - See Section 6, 'Programming Guide', for guidance.

5.7.7 POURING MOTOR WIRES DISCONNECTED

1. Remove the electrical box. Ensure all wires connecting the Arduino to the pouring motor are fully connected.
   - See "Electronics Box Disassembly" videos for instructions on electrical box removal.
2. Check the voltage across the wires connecting the Arduino to the pouring motor using a multimeter. If 0V is read across a wire:
   a. The connection is not complete and the wire needs to be better secured, or
   b. The wire is faulty and needs to be replaced.
3. Remove the pouring tower housing. Ensure all connections between wires and the pouring motor are fully connected.
   - See "Pouring Motor Disassembly" videos for how to remove the pouring tower housing.

4. Check the voltage across the pouring motor using a multimeter. If 0V is read, the pouring motor is broken. Replace the pouring motor with a functioning one, taking care to replace all wire connections accurately.
   - See "Pouring Motor Disassembly" videos for how to remove the pouring tower housing and the pouring motor.

5.7.8 Motor Driver Chip is Broken

This procedure covers debugging techniques for both of the motor driver chips.

1. Remove the electrical box. Locate the motor driver chip and replace it with a functioning chip, taking care to replace all wire connections accurately.
   - See "Electronics Box Disassembly" videos for instructions on electrical box removal.
   - See Appendix O of the Final Design Review Report for a complete wiring diagram of the system.

5.7.9 Pouring Motor is Broken

1. The pouring motor will always provide resistance when it is running. While the wine opener power toggle is in the "On" position, try to rotate the motor manually. If the motor provides resistance, and maintains its position, the motor is still functional. If not, the motor will need to be replaces.
2. The pouring motor may stall if it encounters too much resistance. In most cases, this can be solved by turn the controller off and back on using the power toggle on the control panel.
3. If the pouring motor appears to be too 'jumpy', or gets stuck, remove the gripper and the gripper spacers in order to apply a layer of grease between the spacers and the housing.
   - See the "Gripper Disassembly" video within the "Pouring Motor Disassembly" videos folder for instructions on removing the gripper.

5.7.10 Linear Servo is Broken

1. Check that all wires between the linear servos and the servo driver are connected and not damaged. Check the resistance across the wires to check that they will still transmit power. If the wire is broken, replace it.
2. Measure the voltage across the servo driver pins to see that it provides power signal and ground on the appropriate wires.
   a. If it is not getting power, check if the 6V power converter is plugged in and supplying power to the custom PCB that the servo driver pins are attached to. If it is not connected, connect the 12V and 6V ends to the 12V out and 6V in pins on the custom

PCB. If the 6V power converter is not supplying 6V while receiving 12V it will need to be replaced.

b. If the servos are receiving power from the motor but not a signal, check the connection from the Arduino to the PCB and replace the wire if necessary.

c. If a signal is not being sent from the Arduino microcontroller, this is either a code issue or the data pin may be broken. The servo can be reconnected to any available PWM pin on the Arduino. You will need to change the pin assignment in the control code to reflect the new pin. (see Section 6, 'Programming Guide')

   - If a signal is still not being sent from the Arduino microcontroller, the Arduino may be broken. See section 5.7.2.

3. If the servo is receiving the correct power and signal, the servo is broken and must be replaced.

5.7.11 Linear Servo is Not Squeezing Enough

This issue may present the same symptoms as dull foil cutter blades. Be sure that the blades have been replaced before proceeding to the following. (see section 4.2.2)

1. Check that foil cutter brackets are moving towards the center of the foil cutter along with the linear servo arms. If the linear servo arms are moving but the brackets are not, make sure that the screw pin is still in place. Replace if necessary.

2. If the new blades are not cutting the foil, the tightness of the linear servos can be adjusted in the code, if necessary. (see Section 6, 'Programming Guide')

5.7.12 Foil Cutter Servo Not Rotating

1. If the foil cutter is rotating when the tower rotates, then the servo has been reset. The servo will need to be reprogrammed to ID #2. (see Section 6, 'Programming Guide')

2. Check that all wires between the Dynamixel servo and the servo driver are connected and not damaged. Check the resistance across the wires to check that they will still transmit power. If the wire is broken, replace it.

3. The foil cutter servo is connected through the tower rotational servo but can also be connected directly to the servo shield on the Arduino. If the foil cutter servo works when directly connected, check the wire between the shield and tower servo as well.

4. Measure the voltage across the servo driver pin to see that it provides power signal and ground on the appropriate wires.

   a. If it is not getting power, check if the 6V power converter is plugged in and supplying power to the custom PCB that the servo driver pins are attached to. If it is not connected, connect the 12V and 6V ends to the 12V and 6V pins on the custom PCB. If the 6V power converter is not supply 6V while receiving 12V, it will need to be replaced.

   b. If the servos are receiving power from the motor but not a signal, check the connection from the Arduino to the custom PCB and replace the wire if necessary.

   c. If a signal is not being sent from the Arduino, the servo control shield may be connected incorrectly or broken. Check that Arduino pin 53 is connected to the slave select pin on the shield, and that the code initializes the shield with pin 53.

5. If the servo is receiving the correct power and signal, the servo is broken and must be replaced.

5.7.13 Stepper Motor is Not Working

1. Check that all wires between the foil linear servos and the motor driver chip are intact, show no damage, and still transmit power through them. If they do not function as intended, replace.

2. Measure the voltage across the motor driver chip to see if still functional. If no voltage, replace the chip.

3. If both of these are functional, then the stepper motor is broken and must be replaced.

5.7.14 Corkscrew Has Stalled

A stalled corkscrew is indicated by a high-pitch whine coming from the corkscrew. This can be due to either an alignment issue or an issue where the corkscrew is not receiving enough power.

1. Check that the corkscrew entered the cork in the center.

   a. If it has not, make sure that the bottle is centered in the gripper before operation. If not centered, the screw will run into the glass on the inside of the neck and will stall when it cannot continue rotating.

   b. If the bottle is centered in the gripper but the corkscrew still does not enter the cork in the center, refer to section 5.7.18 for help on centering the corkscrew by means of the rotating tower.

2. Remove the cap to the corkscrew housing and check that the corkscrew is receiving 5V across its terminals.

   - Refer to section 4.2.1 for instructions on how to access the corkscrew.

3. The corkscrew features an internal cutoff switch that shuts off the motor in the forward direction when a cork has been pulled. If the switch is bypassed, the motor will stall when the cork reaches the top of the screw. In this case, the corkscrew will need to be replaced.

5.7.15 Corkscrew Did Not Run For Long Enough

1. If the corkscrew did not begin to enter the cork when the corkscrew motor first starts, then the cork may not be fully removed. This is likely caused by a particularly dense or hard cork in which the corkscrew does not have enough weight to drive itself into.

   - If this type of cork is going to be used in the machine often, it is advised that you remove the main tower housing and add a small amount of weight to the floating gantry in order to get the corkscrew to drive.

    - See "Rotating Tower Disassembly" videos for instructions on how to remove the main tower housing.
  - If this is cork will rarely be used with the wine opener, you can get the corkscrew to drive by running the machine again and applying a downward force on the arm of the corkscrew until the corkscrew has been driven into the cork.
2. If the corkscrew was not properly aligned with the bottle when the corkscrew motor first starts, the main tower may not be centering the cork properly. See section 5.7.18.
3. The tower's powered gantry may not have moved down far enough to allow the corkscrew to fully drive into the cork. This may be indicated by a pull on the tower from the corkscrew. See section 5.7.21 for instructions on how to troubleshoot the gantry height.
4. The corkscrew may be worn down and no longer sharp enough to penetrate the cork. See section 4.2.1 for instructions on how to replace the corkscrew.

5.7.16 Corkscrew Does Not Eject Cork

1. The bypass diode may be broken or disconnected.
   - With the device off, push in and hold the Tasting pour button. Turn the device power on, then turn the controller on using the on/off toggle (while still holding in the Tasting button). When the button's LED ring turns yellow, release the switch. The corkscrew should run in reverse before proceeding with normal startup. If it does not run, the corkscrew wiring will need to be checked.
   - Refer to Section 4.2.1 for details on how to access the corkscrew and how the corkscrew needs to be wired to work with the wine opening system.

5.7.17 Rotating Base is Not Well-Lubricated

1. Remove the electrical box. Apply grease to the lazy Susan ball bearing located between the base plate and the rotating tower.
   - See "Electronics Box Disassembly" videos for how to remove the electrical box.

5.7.18 Centering Setpoints are Incorrect

See Section 6, 'Programming Guide', for assistance in changing the main tower rotating setpoints.

- See "Electronics Box Disassembly" videos for instructions on how to remove the electrical box.
- Refer to Section 6.1 for instructions on uploading code to the Arduino.

5.7.19 Main Tower Servo Not Rotating

1. The servo shield takes about 5 seconds from powering on the controller until it will communicate with the motors. If the tower does not respond in the first few seconds of operation, ensure that the control code pauses long enough before proceeding with any operations.

2. If the foil cutter servo is not rotating in addition to the main tower servo, the servo control shield may need to be replaced, or the slave select wire to pin 53 may be loose.
3. If the tower seems to be getting stuck, check for any obstructions that may be blocking the tower rotation. Also try applying a coating of grease to the tower turntable bearings.
4. If the problem persists, the rotational servo may need to be replaced.

5.7.20 Too Much Friction in Stepper Motor

1. Check for any obstructions or pinched wires in the tower's path.
2. If the wine opener is making a lot of noise when the stepper motor is trying to run, the lead screw may be rubbing against the bottom side of the housing cap.
   - Remove the cap from machine and place an additional spacer between the tower and the cap.

5.7.21 The Tower was not Reset between Operations

If the tower does not return to its top position in between runs, the tower will not raise the tool arms high enough.

1. If the tower moves smoothly (does not appear to be skipping), modify the "TowerUp" calls in the code to move the tower to the appropriate locations.
   - The tower should stop when the upper limit switch is triggered, so overshoot is acceptable.
   - See Section 6, 'Programming Guide', for details on how to modify the code.

5.7.22 Connection to Arduino Has Been Broken

1. If you can hear the relays clicking but the LEDs do not turn on:
   a. A connection has probably been broken
      - Inspect the wiring between the relay board, the buttons, and ground.
      - Pay special attention to the soldered connections to the resistors behind the buttons.
2. If you cannot hear the relays clicking and the LEDS do not turn on:
   a. Check the control pins are correctly connected to the Arduino microcontroller.
      - Please reference the complete wiring diagram in Appendix O of the Final Design Review Report for correct pin connections.

5.7.23 Power to Button Disconnected

If none of the LEDS are turning on, but the relays are still activating (you can hear them clicking), remove the electrical box and check the 12V power wiring (thick red wires) for faults.

1. Remove the electrical box and look for broken wires.
   - Replace any broken wires.
2. Ensure that all connections are secured into their proper pins or terminals.

- Please reference the complete wiring diagram in Appendix O of the Final Design Review Report for proper pin connections.

5.7.24 The Switch is Shorted to Ground

The controller defaults the input pin to high (active low). The controller will think that a button has been pressed if the connection to that input has been shorted to ground.

1. Remove the electrical box and look for broken wires or exposed connections in relation to the function that is running when it should not be.
   a) Check the data wiring to the emergency stop button for faults.
   b) Check the data wiring for faults.
   c) Check the continuity on the button to see if it is stuck in the "on" state.
2. Replace broken wires.
3. Use electrical tape or heat shrink to cover exposed connections.

5.7.25 The Switch is Shorted to Power

The controller defaults the input pin to high (active low). The controller will never register a button press if the connection to that input has been shorted to power.

1. Remove the electrical box and look for broken wires or exposed connections in relation to the function that is running when it should not be.
   a) Check the data wiring for faults.
   b) Check the continuity on the button to see if it is stuck in the "off" state.
2. Replace broken wires.
3. Use electrical tape or heat shrink to cover exposed connections.

5.7.26 The Relays May Not Be Connected To Power

Check to see if you can hear the relays clicking when a pour size button is pressed. If the relay is clicking for one button and not another, the issue may be with that button or specific relay. If you cannot hear any of the relays clicking, they may not be connected to power.

1. Remove the electrical box and inspect the power supply to the relay module.
2. Ensure that all power connections are secure in their terminals and pins.
3. If the problem persists, the relay may be broke. Please see Section 5.7.27.

5.7.27 The Relays May Be Broken

1. If none of the relays are clicking when you press a pour size button, first check to see that the relay board is receiving power.
2. If one relay is not clicking when you press the button, move the wires to the extra relay and see if that fixes the problem. If this does not, the relay board will have to be replaced.

6 PROGRAMMING GUIDE

This section covers the process for making changes to the control code for the wine opener. The device is designed to work with an Arduino Mega 2560 R3 microcontroller board or similarly-equipped clone board. The hardware and open-source software are widely available, as is support and documentation.

6.1 REPROGRAMMING THE CONTROLLER

The controller code can be modified by connecting a standard USB B-type cable between the jack on the Arduino and a computer. To access the Arduino, the lower enclosure must be removed, along with the internal spill guard. **Always unplug the main power connector before removing the lower enclosure.**

To work with the code, the free Arduino Software (IDE) can be downloaded from Arduino's website (https://www.arduino.cc/en/Main/Software). Versions exist for Windows, Mac, and Linux computers. All 15 files (see "Code Overview" below) must be placed in a folder called "WineOpenerCode" (the same name as the main control file, but without the '.ino' extension). The code can then be loaded by opening the main WineOpenerCode.ino file.

6.2 CODE OVERVIEW

The control code was written in Arduino Sketch, an offshoot of C/C++. The code package consists of fifteen (15) files:

- a main control file, 'WineOpenerCode.ino';
- a header file with control parameters, 'globals.h';
- seven (7) C++ source files containing code for each of the device's functions;
- three (3) pairs of header/source files for external libraries: 'Dynamixel_Servo', 'ServoCds55', and 'WheatstoneBridge'

6.2.1 MAIN CONTROL FILE

WineOpenerCode.ino

This control file performs three functions: handles interrupts for the emergency-stop button, initializes all systems, and runs the main control program. Of particular interest will be the main control loop, contained within the `void loop()` function. Within this function, tasks are executed in sequential order.

6.2.2 Header File

globals.h

The header file contains macro definitions for the many parameters that control the system, as well as C function prototypes. By editing this file, many of the aspects of the system can be changed.

6.2.3 Function Source Files

corkscrew.cpp, foil.cpp, interrupts.cpp, loadcell.cpp, pouring.cpp, tower.cpp, ui.cpp

These seven files contain the driver routines needed to run the device. Functions are implemented in such a way that individual operations have their own functions (TurnTower, CutFoil, PourVolume, etc.). These files should not need to be modified.

The file interrupts.cpp exists to provide support for features that are not currently implemented.

6.2.4 External Libraries

Dynamixel_Servo.h/cpp, ServoCds55.h/cpp. WheatstoneBridge.h/cpp

These files allow for interaction with the hardware that drive the pouring servo, tower/foil cutter rotational servos, and weight sensor, respectively. They are open-source files from third-party developers that were used, unmodified, for this device.

These files were obtained from the following sites:

- Dynamixel_Shield: Michael Krzyzaniak, Github, https://github.com/michaelkrzyzaniak/Dynamixel_Servo
- ServoCds55: RobotShop, https://www.robotshop.com/media/files/zip2/rb-dfr-237_-_arduino_library_-_servocds55.zip
- WheatstoneBridge: RobotShop, https://github.com/RobotShop/Wheatstone-Bridge-Amplifier-Shield/archive/master.zip

6.3 MODIFYING THE CONTROLLER

6.3.1 Main Control Sequence

The Main Control File can be edited to alter the timings and sequence of operations of the device. It is recommended to change this file **only if there are issues with the device timing.**

Available options include:

- Timing within the `delay()` calls (units of milliseconds) can be adjusted to make the device pause for longer or shorter amounts of time.

CAUTION: shortening some delays may cause operations to overlap and not work as expected!

- The emergency stop can be ignored by setting the `state` variable to 0, and re-enabled by setting it to 1.

6.3.2 Runtime Parameters

The declarations in the Header File govern many system parameters, from the bottle pouring angle limits to the tower positioning. Each of the user-modifiable parameters is described below:

Parameter	System	Description	Default Value	Units	Min Value	Max Value
FOIL_ANGLE	Tower	Angle to position the foil cutter over the bottle	213	deg	0	300
CORK_ANGLE	Tower	Angle to position the corkscrew over the bottle	25	deg	0	300
START_ANGLE	Tower	Starting and rest position of the tower	152	deg	0	300
CORK_DROP_ANGLE	Tower	Angle to position the corkscrew over the cork drop point	95	deg	0	300
FOIL_DROP_ANGLE	Tower	Angle to position the foil cutter over the cork drop point	280	deg	0	300
ALIGN_OFFSET	Tower	Angle increment to use for ensuring the alignment over the bottle	12	± deg	0	150
FOIL_DOWN_DIST	Tower	Distance between the top of the tower and the foil cutter's lowest position	2800	steps	0	10000
CORK_DOWN_DIST	Tower	Distance between the top of the tower and the corkscrew's lowest position	3000	steps	0	10000
OVERHEAD_DIST	Tower	Distance between the top of the tower and the intermediate working height of the tower	0	steps	0	10000
TOWER_TURN_SPEED	Tower	Speed for tower rotations	27	-	0	1023
CUTTER_TURN_SPEED	Foil Cutter	Speed for foil cutter rotations	70	-		
FP_START	Foil Cutter	Start angle for the foil cutter	60	deg	0	300
FP_END	Foil Cutter	End angle for the foil cutter	300	deg	0	300
LS_OUT[1]	Foil Cutter	Open position for the foil cutter blades	1000	-	1000	1640
LS_IN[1]	Foil Cutter	First cutting depth for the foil cutter blades	1445	-	1000	1640
LS_INC	Foil Cutter	Increase the cut depth by this much for sequential passes	40	-	0	640
CORK_TIME_IN	Corkscrew	Length of time to run the corkscrew for cork removal. The motor automatically stops when the cork is fully removed, but this timer will still run for the full duration.	8700	msec	0	-

CORK_TIME_OUT	Corkscrew	Length of time to run the corkscrew for cork ejection	5500	msec	0	-
TARGET_2OZ	Pouring	Amount to read for a 2oz pour	1.75	oz	0	-
TARGET_4OZ	Pouring	Amount to read for a 4oz pour	4.00	oz	0	-
TARGET_5OZ	Pouring	Amount to read for a 5oz pour	4.70	oz	0	-
POUR_MARGIN_1	Pouring	Fraction of volume left to start slowing down pour	0.15	%	0	1
POUR_MARGIN_2	Pouring	Fraction of volume left to stop pouring	0.06	%	0	1
RATE_FAST	Pouring	Upper limit of initial pouring rate	0.125	g/sec	0	-
RATE_SLOW	Pouring	Lower limit of initial pouring rate and upper limit of finishing pour	0.080	g/sec	0	-
RATE_CUTOFF	Pouring	Lower limit of finishing pour. Should be set to slowest rate that will still pour.	0.070	g/sec	0	-
SPD_START	Pouring	Pouring motor speed for intermediate (non-pouring) movements	0.75	rad/sec	0.03	-
SPD_UP	Pouring	Pouring motor speed for pouring movements	0.20	rad/sec	0.03	-
SPD_STOP	Pouring	Pouring motor speed for finishing movements	0.08	rad/sec	0.03	-
ANGLE_INC	Pouring	Amount to change the pour angle by during pouring steps	0.003	rad	0	-
INC_MAX	Pouring	Amount to change the maximum angle limit, based on how much wine has already been poured from the bottle	0.011	rad/oz	0	-
ANGLE_HIGH[2]	Pouring	Maximum allowable angle to raise the bottle	1.15	rad	0	6.28
ANGLE_UP[2]	Pouring	Initial pouring maximum angle	1.41	rad	0	6.28
ANGLE_START[2]	Pouring	Angle to begin a pour from	1.57	rad	0	6.28
ANGLE_STOP[2]	Pouring	Angle to slowly retreat to after finishing a pour	1.65	rad	0	6.28
ANGLE_DOWN[2]	Pouring	Angle to set the bottle in its down (rest, loading) position	3.10	rad	0	6.28

Current as of controller revision 1.1, 8 June 2018

[1] The foil cutters take a signal between 1000-2000. Therefore, the travel range of the motor is given by (signal – 1000) / 10 %. The servos max out at 64% closed (signal of 1640) due to the blade arms.

[2] The pouring motor is set up such that the angle increases in the counter-clockwise direction (when viewed from the front of the device). This means that the angle decreases as the bottle is raised, and decreases as the bottle is lowered.

6.3.3 PIN TABLE

The Pin Table is contained in the Header File below the Runtime Parameters. It documents the wires connected directly to the Arduino Mega microcontroller. These pins do not need to be changed unless the wiring is modified.

6.4 RESETTING THE DYNAMIXEL SERVOS

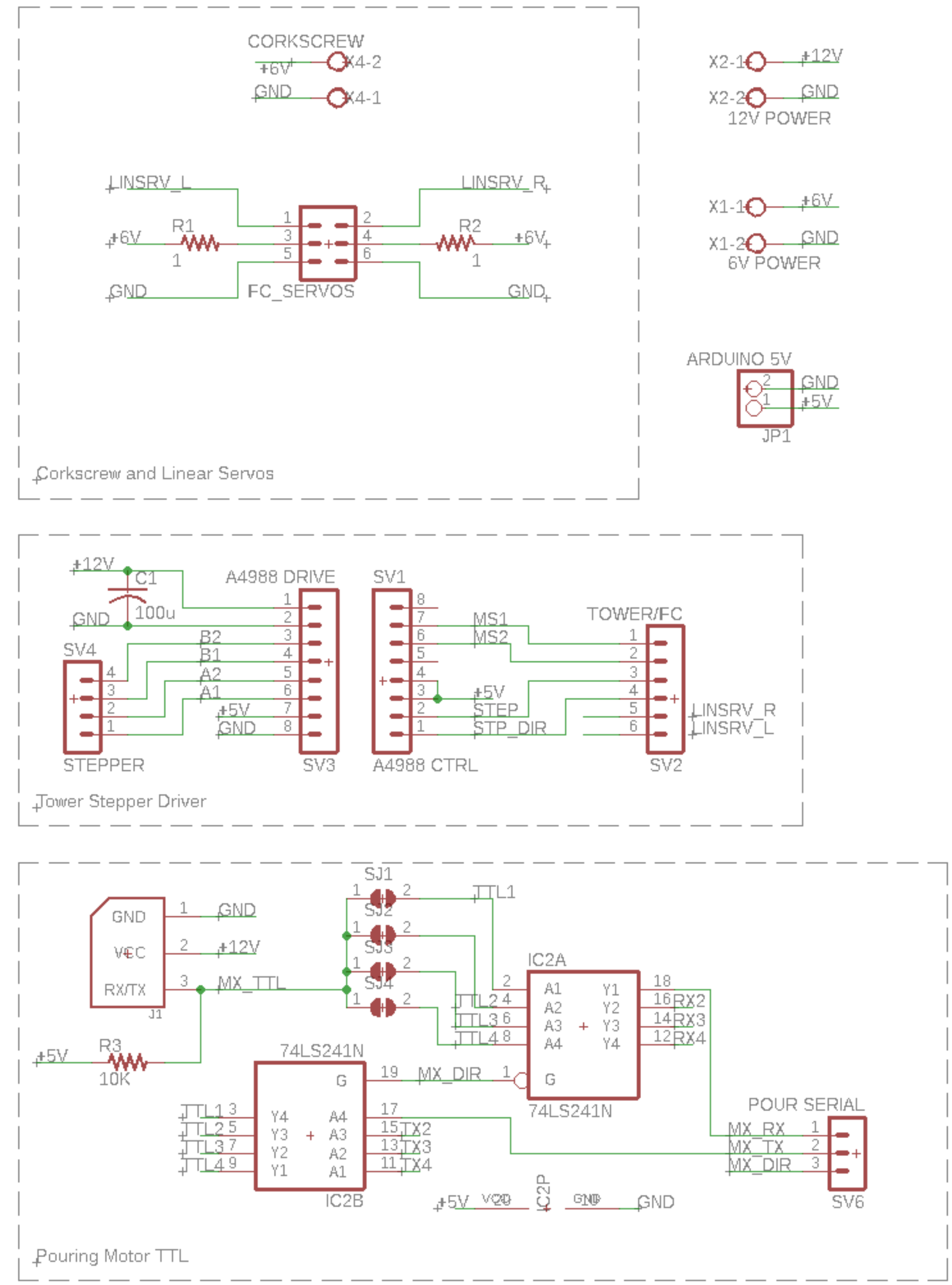
The Dynamixel servos (two AX-12As used for the tower and foil cutter rotational servos, and one MX-64T used for the pouring motor) contain their own microcontroller chips and control algorithms. They support individual IDs and daisy-chaining, and default to ID #1 when reset. The system runs with the pouring motor as ID #1 (on its own control network), the tower servo as ID #1 (through the servo control shield on the Arduino), and the foil cutter servo as ID #2.

Issues will arise if the foil cutter rotational servo is reset, since it will default to ID #1. This causes the foil cutter to rotate with the tower and not on its own. To reconfigure the servo, perform the following steps, in order:

1. Remove the lower enclosure to access the Arduino.
2. Open the **AX12A_reset** program in the Arduino IDE. Set the servoNum variable to 2, then upload the code to the Arduino microcontroller.
3. Unplug the Arduino from the computer. **The entire system should be unpowered and unplugged at this point**.
4. Disconnect the 12V power cable from the purple auxiliary board. Isolate the wire with a wire nut or electrical tape to avoid electrical shorts.
5. Disconnect the tower rotational servo from the servo control shield.
6. Unplug the cable between the two AX-12A servos from the tower servo and plug it into the servo shield. The <u>foil cutter servo should now be directly connected to the shield</u>, and the **tower servo should not be connected.**
7. Plug in the main power, and power up both the device and controller.
8. Allow the reset program to run for ~30 seconds. There will be no indication from the system that anything is happening.
9. Power down the controller and device. Unplug the main power connector.
10. Plug the foil cutter servo back into the tower servo, then reconnect the tower servo to the servo shield.
11. Reconnect the 12V cable to the purple auxiliary board.
12. Reinstall the lower enclosure and reassemble the device.

APPENDIX O: WIRING DIAGRAMS AND PIN TABLES

Custom PCB Electrical Schematic (Rev. 1)



Rev. 1:
- Added 10K pullup resistor between MX_TTL and +5V
- Changed stepper driver module headers from MP6500 to A4988
- Board ground plane Isolation distance increased

Arduino Pin Table

Pin	Pin Functions	Usage	Signal Name	Description	Connected to
0	HW Serial, INT8	Debugging	RXD0	USB serial receive	---
1	HW Serial	Debugging	TXD0	USB serial transmit	---
2	INT4, PWM				
3	INT5, PWM	E-Stop button	ESTOP	Emergency stop interrupt	E-stop button
4	PWM	Stepper motor	STP_DIR	Direction select	Control board pin 4
5	PWM	Stepper motor	STEP	Stepping	Control board pin 3
6	PWM	Stepper motor	MS2	Step divider	Control board pin 2
7	PWM	Stepper motor	MS1	Step divider	Control board pin 1
8	PWM	Linear servos	LSRV	Left servo data signal	Control board pin 5
9	PWM	Linear servos	RSRV	Right servo data signal	Control board pin 6
10	RX, PWM				
11	RX, PWM				
12	RX, PWM				
13	RX, PWM				
14	TX3				
15	RX3				
16	TX2				
17	RX2				
18	TX1, INT3	MX-64T Control	MX_TX	TTL transmit	POUR SERIAL TX (pin 2)
19	RX1, INT2	MX-64T Control	MX_RX	TTL receive	POUR SERIAL RX (pin 1)
20	SDA, INT1				
21	SCL, INT0	MX-64T Control	MX_CONTROL	Data direction	POUR SERIAL pin 3
22	Digital I/O	Limit switch	SW_1	Tower limit switch	Limit switch NORM CLOSED
23	Digital I/O	Button 1 Green LED			Relay channel 8
24	Digital I/O	Toggle 2			
25	Digital I/O	Button 1 Red LED			Relay channel 7
26	Digital I/O	Toggle 3			
27	Digital I/O	Button 2 Green LED			Relay channel 6
28	Digital I/O				
29	Digital I/O	Button 2 Red LED			Relay channel 5
30	Digital I/O	Button 1			
31	Digital I/O	Button 3 Green LED			Relay channel 4
32	Digital I/O	Button 2			
33	Digital I/O	Button 3 Red LED			Relay channel 3
34	Digital I/O	Button 3			
35	Digital I/O				
36	Digital I/O				

37	Digital I/O	E-stop LED		LED for E-stop button	Relay channel 1
38	Digital I/O				
39	Digital I/O				
40	Digital I/O				
41	Digital I/O				
42	Digital I/O	Corkscrew	INA		VNH board INA
43	Digital I/O	Corkscrew	INB		VNH board INB
44	PWM				
45	PWM				
46	PWM				
47	Digital I/O				
48	Digital I/O				
49	Digital I/O				
50	MISO, RX	AX-12A Control	MISO	SPI receive	DSS shield MISO (through ICSP header)
51	MOSI, RX	AX-12A Control	MOSI	SPI transmit	DSS shield MOSI (through ICSP header)
52	SCK, RX	AX-12A Control	SCK	SPI clock line	DSS shield SCK (through ICSP header)
53	SS, RX	AX-12A Control	AX_SS	SPI slave select - servo shield	Servo shield pin 10
A0	Analog I/O	Load Cell	LOADCELL1	Load cell shield analog signal	
A1	Analog I/O	Load Cell	LOADCELL2	Load cell shield analog signal	
A2	Analog I/O				
A3	Analog I/O				
A4	Analog I/O				
A5	Analog I/O				
A6	Analog I/O				
A7	Analog I/O				
A8	Analog I/O				
A9	Analog I/O				
A10	Analog I/O				
A11	Analog I/O				
A12	Analog I/O				
A13	Analog I/O				
A14	Analog I/O				
A15	Analog I/O				

VNH5019 Carrier Pin Table

Pin	Signal Name	Description	Connected to
1	INA	Channel A signal	Arduino pin 42
2	ENA/DIAGA	Channel A enable	--
3	PWM	PWM frequency (100%)	5V (logic HIGH)
4	CS	Current sense	--
5	ENB/DIAGB	Channel B enable	--
6	INB	Channel B signal	Arduino pin 43
7	VDD	Logic power supply	5V
8	GND	Ground (common)	Ground
9	VOUT	Motor power out	--
10	GND	Ground (common)	--
T1	VIN	Motor power	Aux board +6V (Terminal 3-1)
T2	GND	Ground (common)	Aux board ground (Terminal 3-2)
T3	OUTB	Channel B output	Corkscrew - (blue/black wire)
T4	OUTA	Channel A output	Corkscrew + (yellow wire)